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VOLUME 16 FEBRUARY 1937 NUMBER 2

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Welding in Construction*

By GILBERT D. FISH†

OUR topic is the design of welding connections for steel-frame structures, such as buildings and bridges, and the influence of such connections on the design of the members which they join.

A welded connection may be simply a weld or a group of welds, directly connecting members of a structure to each other, or else a combination of welds and one or more connection pieces designed to transmit stress directly from one member to another through the connection pieces.

The only kind of welding we are considering is fusion welding, in which filler metal is deposited in prescribed spaces between the base-metal parts to be joined. It is a cardinal principle of structural welding, that every weld shall be predetermined in form, dimensions and location, in such manner that the maximum stresses are known to be within safe limits.

Two fundamental weld forms are recognized, both prismatic and differing only in respect to cross sections. They are the butt weld and the filled weld, of which satisfactory definitions have yet to be devised, but which can be illustrated so that they are easy to distinguish for most practical purposes.

In Fig. 1 appears a joint, in which a plate or beam web meets another member at right angles and is connected to it directly by two fillet welds. The critical section of each weld is considered to be the longitudinal or axial section through the throat, which is marked on the figure. A longitudinal or shearing force S transmitted through this joint induces shearing stresses in the critical sections of the welds, having a mean intensity equal to half of S divided by the area of the critical section of each weld. This area is the throat dimension multiplied by the weld length. If the weld surface is convex, instead of flat as in the figure, the throat dimension is not considered to be greater than the altitude of the inscribed triangle. Although the shearing stress is not uniformly distributed through the critical section, the mean value is what is meant by the AMERICAN WELDING SOCIETY Building Code and Bridge Code, where limiting values for shearing stress are prescribed.

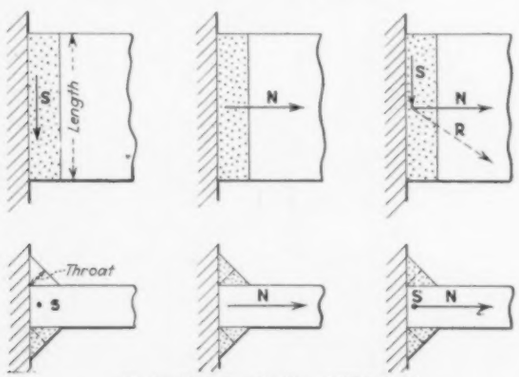


Fig. 1—Illustrating the Use of Fillet Welds

* A Lecture Under the Auspices of the New York Section of the AMERICAN WELDING SOCIETY and the Polytechnic Institute of Brooklyn at Brooklyn, New York on December 22, 1936.

† Consulting Engineer.

Figure 1 shows also the same joint subjected to a normal force N, whose line of action passes through the midpoint of the joint. Half of this total stress N, divided by the area of critical section of one weld, is the mean intensity of stress. This stress is neither normal nor tangential to the critical section; it is oblique and is therefore a combination of tension and shear. It is not necessary, even if it be possible, to analyze this stress, because the intensity calculated as described is the value for which safe limits have been determined by tests. In the Codes above mentioned, the permissible shearing stress values are applied to this case. The stress is regarded as uniformly distributed only when the line of action of the applied stress passes through the midpoint of length.

Fig. 2—Butt Weld in Plate of Same Thickness

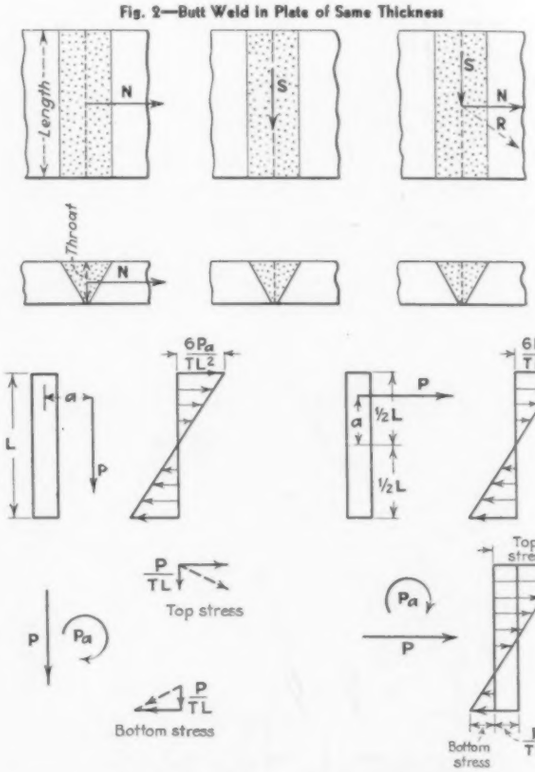


Fig. 3—Accounting for Eccentrically Applied Stresses

Figure 1, at the left, shows the same joint subjected to a combinatiou of stresses S and N, the resultant of which is R. Half of R is divided by the critical area of one weld to determine the mean intensity of critical stress. The normal stress N being applied at the midpoint of length, the stress is regarded as uniformly distributed and is permitted to reach the limiting values specified for shearing stress in the Codes. From the foregoing it will be seen, that in designing a fillet weld, the critical stress is taken as the total applied force divided by the

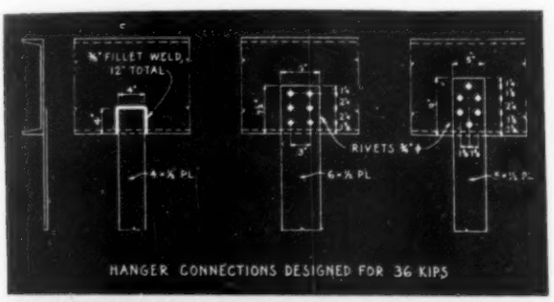
critical area, regardless of the direction of that force, in all cases where the line of action of the force passes through the midpoint of the weld.

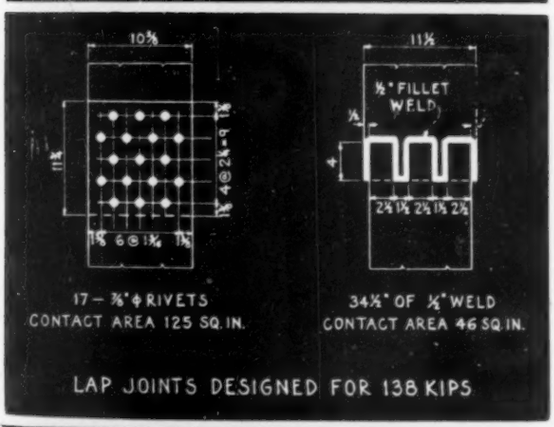
Figure 2 shows a butt weld joining two aligned plates of equal thickness. The throat dimension of the weld is considered equal to the plate thickness, even though the weld surface be rounded or reinforced so that its physical thickness is greater than the plate thickness. A longitudinal shearing stress S and a normal stress N are shown separately and in combination. In the middle diagram, which represents a case of longitudinal shear, that shear is conventionally treated as if it were uniformly distributed through the rectangular section formed by the length and the throat, even though it is known that the maximum stress is appreciably higher than the mean value. The Codes prescribe limiting values for shear, which are not to be exceeded by the mean shearing stress calculated as above described. In the diagram at the left, the stress on the critical section is pure tension and it is regarded as uniformly distributed when the line of action of the applied stress passes through the midpoint of the section. Limiting values of tensile stress are prescribed by the Codes. If the stress N were reversed in direction, the stress on the critical section would be pure compression and its value would be calculated in the same manner as in the case of tension, but, at least in the case of the Building Code, the allowable value would be higher than in case of tension. The case of an oblique resultant stress, illustrated by the diagram at the right should be investigated with respect to the longitudinal or shearing stress and also with respect to the resultant stress; the former should be limited in value to the figure permitted for shear and the latter should be kept within the limit prescribed for direct stress. Some engineers may believe that the normal component of stress rather than the oblique resultant is the critical value for direct stress, but it is on the safe side and probably nearer the facts to use the resultant.

Figure 3 shows the most severe and probably the most accurate method of accounting for eccentrically applied stresses. The dotted rectangle of length L represents the critical section of a fillet weld or a butt weld. The left-hand force diagram shows a force P acting parallel to the weld axis at an eccentric distance a. This combination is equivalent to a longitudinal shear P plus a moment $P.a$. The shear induces a shearing stress P/TL, T being the weld throat. The moment induces a stress normal to the weld axis, which varies uniformly from a maximum value at one end to an equal minimum value at the other end, as shown by the double triangle in the figure. The section modulus of the rectangular area being $TL^2/6$, the intensity of stress at either end is $6Pa/TL^2$. To find the maximum resultant stress, it is necessary to combine this transverse stress due to moment with the longitudinal stress due to shear, as shown by the vector diagrams. In the right-hand half of the figure, the same rectangular section is shown, subjected to an eccentric force normal to the axis of the weld. The moment is again Pa and the uniformly varying stress due to it is determined as before. The force P, acting through the midpoint of the weld, induces a uniform transverse stress equal to P/TL, which is parallel to the varying stress due to moment. The combination is determined by simple addition and subtraction, the result being as shown diagrammatically in the lower right-hand stress diagram. Some interesting tests at Lehigh University have shown that, while this analysis is probably quite accurate up to the elastic limit of the materials, it is considerably on the safe side with respect to ultimate strength, the yielding of the extreme fibers causing an improved distribution of stress as compared with the triangular distribution used in this analysis.

A few designs of simple joints will be illustrated, partly as examples of useful types, and partly for the purpose of showing the methods of calculating their safe capacities. These illustrations will be based on the Building Code rather than the Bridge Code. The Building Code prescribes 13,000 lb. per square inch for tension, 18,000 for compression, 11,300 for shear and also for the oblique stress occurring in transversely loaded fillet welds. The Bridge Code is much more complicated; it not only provides two distinct sets of values for welds of different quality, but it expresses each value as a function of live and dead loads, in order to account for the reduced resistance of welds to frequently repeated live load application. Most of the joint types illustrated are applicable to bridge design and are analyzed in the same manner for bridges as for buildings, but the allowable stresses are different.

Figure 4 shows a lap connection for a plate hanger. A welded design and two riveted designs for the same duty are shown. The three fillet welds forming the welded connection are each $^3/_8$ in. in width and 4 in. long. A $^3/_8$-in. fillet weld has a throat dimension approximately 0.7 of its $^3/_8$ in. width and a stress of 3000





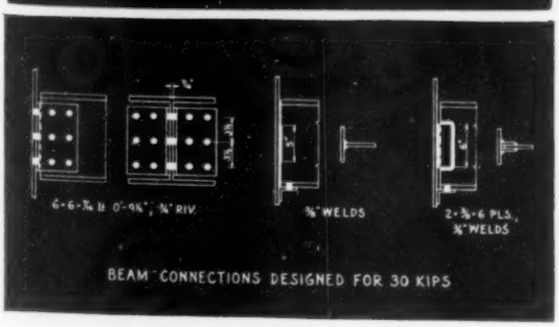


Fig. 4—Top Fig. 5—Center Fig. 6—Bottom

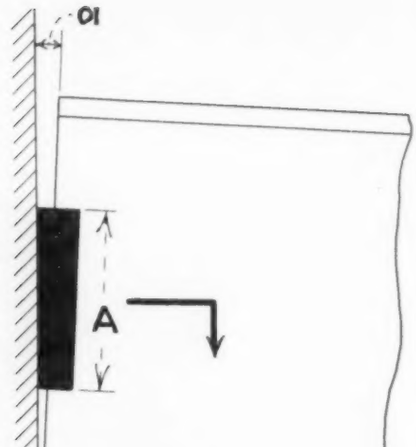
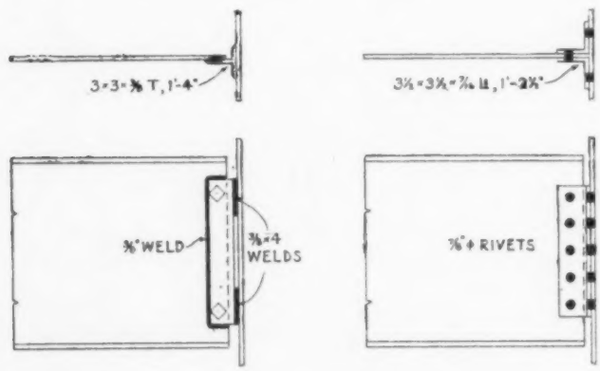


Fig. 7

lb. per lineal inch of such a weld corresponds to the 11,300 lb. per square inch allowed by the Building Code. Four lineal inches can be stressed to 12,000 lb. and 3 welds of 4 in. length have a combined safe capacity of 36,000 lb., regardless of the fact that they lie in different positions with respect to the direction of stress. It is not considered necessary to analyze the two designs shown for riveted construction, except to point out that the hanger itself must be of larger cross section when rivets are used in order to compensate for the loss of section at the rivet holes.

Figure 5 is another lap joint, such as might be used in a tension splice or an end connection of a truss member. In the case of the welded joint detail, the slots in the splice plate are used to increase the length of the edge



BEAM CONNECTIONS DESIGNED FOR 42 KIPS

Fig. 8

along which fillet welds may be placed, thereby saving considerably in the size of plate and weight of joint. The $^1/_2$-in. fillet welds may be stressed to 4000 lb. per lineal inch, and this figure multiplied by the total weld length gives the total safe capacity, which is 138,000 lb. as marked on the figure. The compact nature of welded joints is well exemplified by this detail, which requires a contact area of 46 square inches, as compared with 125 square inches in the rather compactly designed detail for riveting shown on the same figure. In the welded detail, the slotted part is supposed to be the splice plate or connection piece; its critical section is at the inner ends of the slots and its necessary thickness is calculated as follows: three strips $2^1/_2$ in. wide are figured at 18,000 lb. per sq. in. and two sections $1^1/_2$ in. wide at the ends of the slots are figured at the allowable load on the welds. Thus, $3 \times 2^1/_2 \times T \times 18{,}000 + 2 \times 1^1/_2 \times 4000 = 138{,}000$, or $T = {}^{15}/_{16}$ in. The main member, not being slotted, suffers no loss of section.

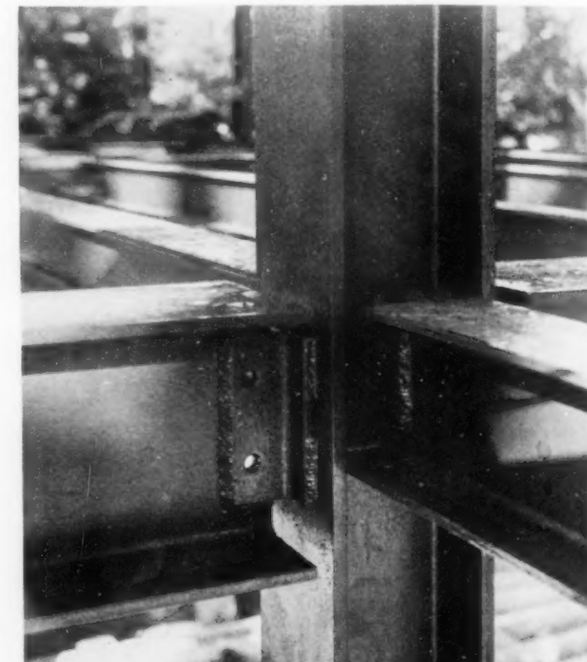


Fig. 9—Yale-Berkeley College

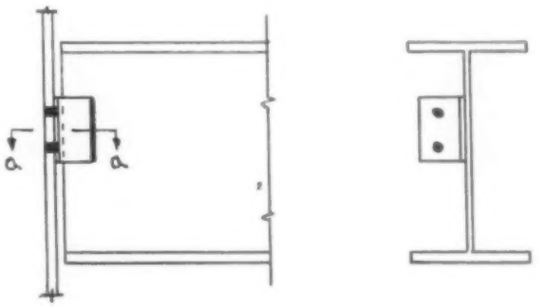
Figure 6 shows two types of welded beam connections and an equivalent riveted detail. The middle figure represents a direct-weld type of web connection which has been used as the prevailing form of beam connection throughout a number of welded buildings within the last three years. Its excellence lies largely in its simplicity. The beam web may be in contact with the face of the supporting member or may be separated from it by a narrow gap amounting to $^1/_{16}$ in. or $^1/_8$ in. It is considered, on the basis of tests and experience, that a separation not exceeding $^1/_{16}$ in. does not reduce the strength of fillet welds joining the parts across the gap, at any rate in cases of fillet welds not less than $^1/_4$ in. in size. A $^1/_8$-in. gap is considered to reduce the effective size of the fillet welds by $^1/_{16}$ in. In order to utilize this type of joint throughout a building, it is necessary that the fabricating shop shall mill one or both ends of most of the beams, not only to correct the considerable variations in length which occur in beams as shipped from the rolling mills, but also in order to insure that the ends of the beams shall be cut square. The

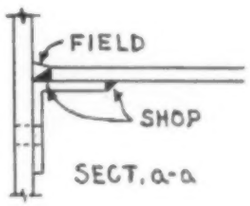
cost of this milling operation is far less than is sometimes supposed and in many cases has been estimated as less than the extra cost of more complicated joints. Naturally this joint type is very economical of welding, because the stress is transmitted directly from the beam into the supporting member through one set of welds instead of through intermediate connection pieces. The joint type shown at the right of this figure includes two plates or bars, which are shop-welded to the beam web and which bridge the gap between the end of the beam and the supporting member; the extra cost of these plates and of the welding necessary to connect them to the beam generally more than offsets the saving accomplished by avoiding the milling of the beam end. In both of these welded joint types, the seat angle is utilized for erection convenience and is frequently disregarded in calculating the strength of the joint because the angle is thin and has not very much resistance.

In both of the joint types illustrated in this figure, there is a distinct lack of flexibility. This feature has advantages with respect to stiffening a building structure but introduces secondary bending stresses due to partial restraint of elastic deflection of the beams. Fig. 7 shows in exaggerated degree the tendency of beam deflection to stretch the fillet welds at the top and compress them at the bottom. It has been fairly definitely established by tests, that if the weld size D is about $^3/_4$ of the web thickness W, or more, the welds are not dangerously strained but are strong enough to cause the beam rotation to be absorbed almost entirely in the web of the beam, where it does no harm. These observations are intended to apply to static rather than dynamic loads. It is questionable whether joints of this type are advisable in bridge floors, where the repeated dynamic loading would be likely to induce fatigue.

The left-hand drawing of Fig. 8 is a welded T-connection which has been used with satisfaction as the prevailing type of beam connection throughout a number of fairly recent building operations. It is fillet-welded to the supporting column or girder along the edges of the flange of the T, the total length and size of this welding being sufficient for the vertical shear. The field welding consists of fillet welds along the line of contact of the stem of the T with the web of the beam, on one side only. In the most recent applications, the stem of the T has been mitered at the corners to facilitate field welding. This field welding is designed for a combination of the vertical shear plus a moment equal to this shear multiplied by the horizontal offset between the face of the support and the center of gravity of the field welding. This joint possesses the advantage of reasonable flexibility combined with simplicity and fair economy of welding. It is occasionally inconvenient in the erection of steel, owing to interference of the outstanding stem with the web or flange of the beam while swinging the latter into place. Figure 9 is a photograph showing two of these T joints, typical of the beam connections throughout a block of buildings at Yale University.

A very adaptable type of web connection for beams, first used about a year ago in the Amherst College gymnasium, is shown in Fig. 10. A light clip angle, usually 2 x $1^1/_2$ x $^1/_4$ or $2^1/_2$ x 2 x $^1/_4$, is shop-welded to the beam web by two fillet welds extending the full length of the angle. The size of the weld at the toe is the same as the angle thickness. The weld joining the heel of the angle to the end of the beam web is a right triangle in section but the legs of the triangle are generally not equal, one being the same as the thickness of the beam web and the other being equal to the projection of the clip angle beyond the beam end. Erection bolts through the outstanding leg of the angle and through the supporting member facilitate erection; as the clip angles at opposite ends of a beam are generally on opposite sides, the beam does not tend to rotate out of position while awaiting field welding. The only field weld is a butt weld joining the supporting member to the shop weld at the end of the beam. As the shop weld forms a bevel at the beam end, the field butt weld is easily made. The safe capacity of this joint, with respect to the vertical shear or beam reaction, is the product of the allowable shearing stress by the length of the joint and the throat of the weld, the latter being equal to the thickness of the beam web. The clip angle and the weld at its toe impart some additional strength, which is disregarded in calculations. As this joint does not include a flexible element, secondary bending stress is to be expected when the supporting member resists rotation of the joint. Therefore, since the stresses in the weld metal are approximately the same as in the base metal adjoining, it is advisable to use high-quality fluxed or covered electrodes for shop and field welds, to insure ample ductility and a yield point higher than that of





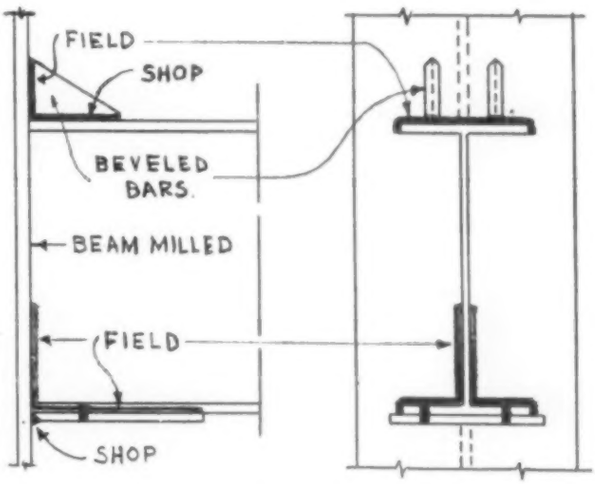


Fig. 10 (Top)—Web Connection for Beams
Fig. 11 (Bottom)—Welded Wind Bracing

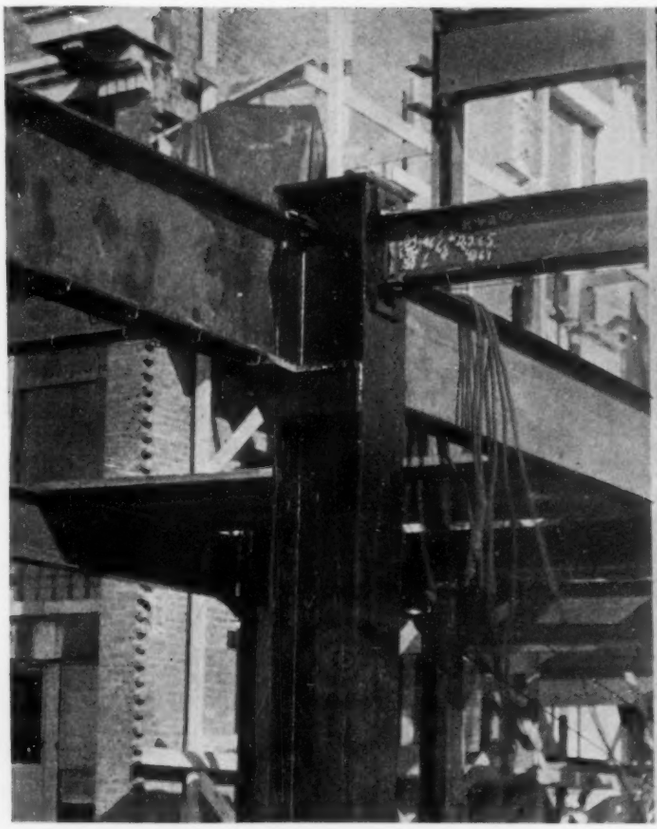


Fig. 12—Connections in Yale Medical Center

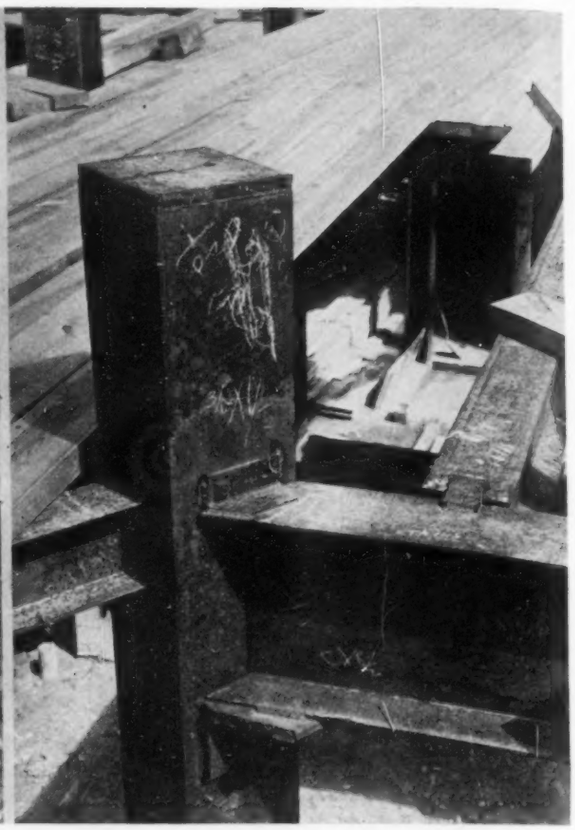


Fig. 13—A Connection for One of Welded Buildings at Yale

the rolled steel. This type of joint is probably unsuitable for bridge stringers and floor beams, inasmuch as stress concentrations at top and bottom make it sensitive to often-repeated dynamic loading. For general building use it appears to be both legitimate and economical, and it is being considerably employed in the Nathan Hale School in Mount Vernon and in the New York State Hospital now being erected in Brooklyn.

A modern example of welded wind bracing is shown in Fig. 11. This is typical of all the full-bending-strength connections in the Brooklyn hospital previously mentioned. Except for some fillet welding along the beam web, intended to resist vertical shear, this joint consists of top and bottom connections designed to resist horizontal stresses equal to the bending resistance of the beam divided by the depth of the beam. Butt welds join the bars or plates to the column and fillet welds join them to the beam flanges. It seems unnecessary to describe the calculations. This type of wind connection should not be designed for a moment less than the bending resistance of the beam itself, because it is rigid enough to restrain or fix the beam completely unless stressed beyond its yield point. For cases where wind moments are small compared with the bending resistance of the beams which they support, semi-rigid connections should be designed. Connections of the latter class also occur in the Brooklyn hospital and have been used in numerous other buildings, including the Trinity College Chemistry Building and a new unit at Kent School, but they are not readily described with satisfactory explanation in a few words; they will, therefore, not be illustrated in this lecture.

Some photographs of welded joints will now be shown, to illustrate without details of calculation various connection forms which have been used in building practice. In Fig. 12 appear two beam-to-column connections, in each of which both flanges of the beam are connected. The wall-beam connection is one in which the seat or bracket is designed for the entire vertical load and the top connection is a brace to steady the top flange and impart a nominal amount of rigidity to the framework. The interior-beam connection is of the class of semi-rigid wind connections, designed to resist vertical shear combined with bending moment considerably less than the bending strength of the beam. These joints are five years old and would probably not be used today because more economical designs for the same purposes are known.

Figure 13 shows a heavy seat angle and top clip angle used to support a skew beam in one of the earlier welded buildings at Yale. It is an effective and reasonably

Fig. 14—Dormitory Building

simple joint, but expensive because of the weight of the angle. Some designers seem to think that rather thin seat angles can properly be used to support heavy beam reactions, but the flexibility of such angles causes the beam reactions to be concentrated very close to the beam ends, thereby endangering the beam webs in case they are rather thin. Laboratory tests of seat angles, made with solid blocks of steel in place of beams, appear to have been misinterpreted sometimes. It seems doubtful whether seat connections, conservatively designed, are generally economical as compared with web connections. It is certain, that the important progress of recent years in lowering the cost of welded building construction, has been closely related to improvements in design of web connections for beams.

In Fig. 14 appears some irregular floor framing, in which beams framing into other beams were cut to fairly exact lengths and fillet-welded web to web without connection pieces. Erection bolts were not used at these beam-to-beam connections, but erection lugs (small plates) were shop-welded to the top flanges of the supported beams, projecting beyond the flange copes so as to support them flush with the tops of the carrying beams. Of course, field measurements were necessary to locate the joints. Another disadvantage was the danger of dislodging an unfastened beam before it was welded. This practice, although it worked out fairly well, was not repeated after it had been used extensively in one block of buildings in 1931.

A typical column splice is shown in Fig. 15. Although the photograph was made over five years ago, it accurately represents present-day practice. The standard splice detail throughout the new Brooklyn State Hospital is the same, except that all the columns are of the 12-in. series and the butt plates are accordingly thinner than in the illustration, and except that the welding extends only 3 in. from each corner. There are excellent reasons, which scarcely need to be pointed out, why the butt plate type of splice is more economical

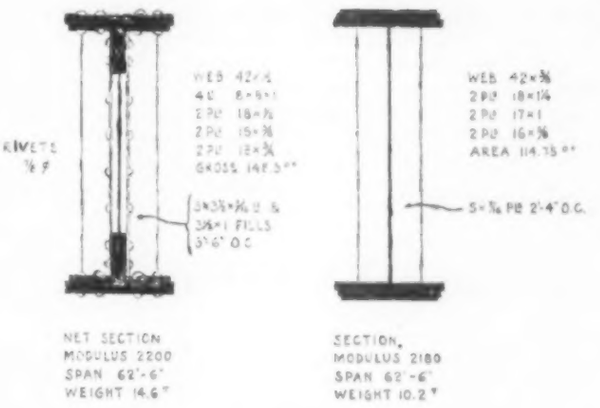


Fig. 16

than any flange plate type with fillers, for welded construction.

Built-up members, such as plate girders and trusses, are somewhat differently designed for welding and for riveting. All the differences make the welded members lighter than their riveted counterparts. In the commonest form of welded girder, the web is welded directly to the flange plates by fillet welds along both sides, the welds usually being continuous near the ends and intermittent elsewhere. Cover plates, if used, are fillet-welded to the main flange plates across the ends and along the edges, the welding being continuous at and near the ends and intermittent elsewhere. Stiffeners are plates or bars set edgewise to the web and fillet-welded to the web and to one or both flanges. Figure 16 shows a central cross section of four girders used across the gymnasium of the Greenwich High School in 1934. Those girders were typical of the design just described. The riveted design shown in the same figure was part of the alternative layout for riveted construction which was estimated in competition. The

Fig. 15—Column Splice

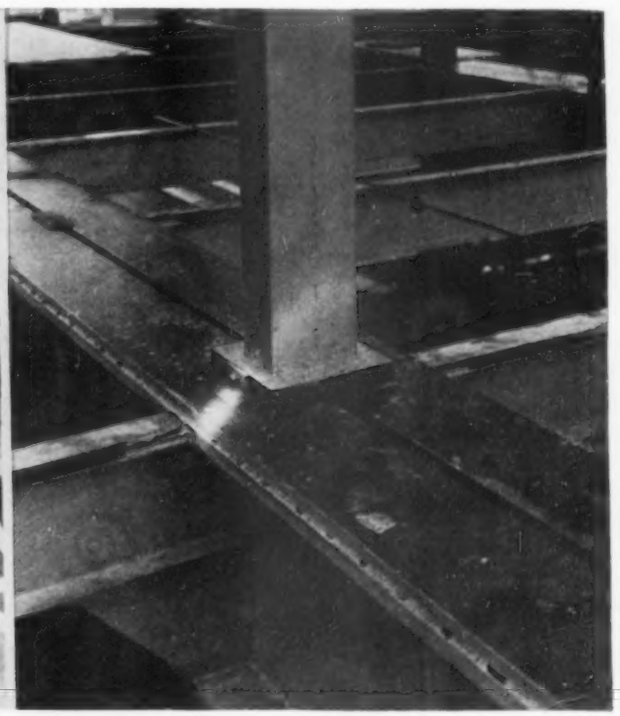


Fig. 17—Welded Girder

girder weights for the two designs, presumably equal in strength, are shown on the drawing. The difference of 30% in favor of the design for welding was due to the following items: the welded girder did not require an allowance for loss of flange section due to rivet holes; the centroids of the flanges were further apart in the case of the welded girder, owing to all flange material being above or below the web; the stiffeners of the welded girder were plates instead of angles and did not require filler plates; the web was thinner for the welded girder, not being weakened by holes, but the reduction of web thickness was partly offset by the necessity for placing the stiffeners closer together. At least one large plate girder has been built with flange angles in addition to flange plates, the purpose of the angles being twofold; the angles avoided the expense of milling or otherwise straightening the web plate and also eliminated the temperature stresses which have sometimes caused trouble in making the fillet welds where a web plate fitted tightly against a heavy flange plate. Generally, flange angles are to be avoided where web stiffeners will be needed. Another variation from the conventional design illustrated is the use of flange plates with splices formed by butt welding; this plan avoids the use of multiple thicknesses and the extra welding required for cover plates, but introduces two or more butt welds in each flange. In view of the relatively low tension values assigned by the codes, butt straps are necessary where butt splices are used in tension flanges, and it therefore appears that such splices should be confined to compression flanges until higher weld stresses are permitted.

Figure 17 is a view of a pair of heavy but not very deep welded girders of the conventional type. Main flange plates and cover plates are slightly under 2 in. thick. The fillet welding joining the plates is intermittent except at and near the ends. Intermittent welding has two advantages over continuous welding, namely, that there is less of it and that the interruptions reduce temperature stresses and distortion due to heat. Fortunately, there is not much difficulty in avoiding distortion in welded girder assembly.

Heavy rolled beams with welded cover plates have been considerably used in welded buildings for five or six years. In many recent buildings, light beam sections have been used with cover plates, for the sake of economy in place of heavy sections of approximately the same depths; the only item of saving, as a rule, is found in the short length of the plates as compared with the beam length. Of course, wherever welded cover plates are used in place of riveted ones, there is the great advantage of saving the rivet holes in calculating flange section.

Welded trusses are well known to be much lighter and less expensive than riveted ones. This is mainly because of the small sizes or complete omission of gusset plates and because of avoiding holes in tension members. The immense variety in truss forms and in truss joints makes it impracticable to deal with the subject at all satisfactorily in a paper of this scope and limited length. Therefore, no illustrations and no further discussion of trusses will be attempted. It may be worth mentioning, however, that a group of 120-ft. roof trusses have been designed with small gusset plates at all joints, avoiding crowded details which would have occurred if the web members had been lapped over the chord angles and saving more than the weight of the gussets in the reduced lengths of the web members.

Continuous-beam design, which welded connections make feasible wherever the arrangement of framing provides opportunity for it, has somewhat disappointed those who expected it to show important economies. The first large welded building, erected at Sharon, Pa., in 1926, was designed with all typical interior connections continuous. With modern knowledge of welded details, it is possible to show economy by continuous-beam design where the beams are not too light to make the weight saving worth while and where the layout is especially favorable.

However, very few of the buildings thus far welded have afforded very favorable opportunities for continuity, and it is worth considering that the extra designing and detailing work must be added to the extra fabrication and welding workmanship in figuring the offsets against the saving in steel.

Corrosion Tests of Welded Low-Carbon Stainless Steel*

LABORATORY tests are frequently used to determine the resistance of a material to corrosion under certain conditions. The value of these tests as an indication of the future behavior of materials in service depends largely upon the type of service and upon the interpretation of the results.

Several methods have been proposed for testing stainless steels, some of which are embodied in specifications for these materials. Three methods have been investigated recently by George A. Ellinger and Leon C. Bibber of the Bureau's Metallurgical Division, in connection with the welding of stainless steel containing about 0.06 per cent of carbon.

A solution of copper sulphate in sulphuric acid did not noticeably attack either plate or weld metal that had been heated to any temperature, although this reagent has been reported to cause intergranular corrosion in stainless steels of higher carbon content.

Concentrated nitric acid was found to attack carbides which had been localized at grain boundaries. The acid attack destroyed the cohesion between the grains by dissolving or decomposing the carbides, thus allowing the grains to become loosened and ultimately to fall away from the material. This type of attack was found only in plate metal which had been heated to 650° C. and which contained carbides localized at the grain boundaries. Carbides in weld metal were usually found in areas of delta ferrite and not in the grain boundaries, regardless of heat treatment; consequently the attack by nitric acid on weld metal was slight.

A solution of hydrochloric acid and water (equal parts) attacked the plate metal severely. Heat treatment of the plate did not appreciably change this rate of attack. Weld metal that was not heat treated was attacked at approximately the same rate as plate metal. After annealing at either 650° C. or 980° C., weld metal was more resistant to attack than plate metal.

The complete report on this investigation will be published as RP963 in the Journal of Research for January.

* Taken from Technical News Bulletin of the National Bureau of Standards, Jan. 1937 issue.

What Happens During Welding and Cutting*

By DR. GEORGE V. SLOTTMAN†

Part I—The Nature of the Oxyacetylene Flame

GAS welding and cutting are processes which require the maintenance of a relatively high temperature at the surface of a material of high thermal conductivity. In steel welding, the steel surface must be heated to the melting point, 2750° F., the heat of fusion supplied to melt the surface and the resulting liquid superheated some hundred degrees Fahrenheit, to insure sufficient fluidity to permit mixing with the molten metal from the welding rod. In steel cutting, the steel surface must be brought to the ignition point with oxygen, some 1500° F. The problem of distortion requires that the heat be confined as far as practicable to the steel surface to avoid heating large masses of the base metal and further from a cost standpoint, confining the heating to the surface of the material reduces the amount of material to be heated and permits of high speed of operation.

In order to maintain a sharp temperature gradient between the surface and interior of a highly conductive material such as steel, a high temperature heat source and conditions favorable to a high rate of heat transfer from that source to the object heated must be maintained. Simply stated, the temperature differential flame to object surface times the specific rate of heat transfer through the boundary between flame and object surface must be greater than the product of the temperature differential between the object surface and interior, and the specific rate of heat conductivity of the object, if the temperature of the object is to be raised.

Since the thermal conductivity of the object to be heated has a fixed value, the rate at which it can be heated and at which the heat of fusion necessary for melting can be transferred will depend on the temperature of the heating flame and on the specific rate of heat transfer through the boundary layer flame to object, the latter depending on a number of factors, including luminosity of the flame, influencing the rate of heat transfer by radiation, and the flame speed and thermal conductivity of the flame gases, influencing the rate of heat transfer by conduction. A further characteristic is required of the heating flame, especially in steel welding. The products of combustion which bathe the surface of the molten steel puddle must protect the steel from oxidation by the air, and must in themselves be non-oxidizing, and, for certain classes of steel welding, actually reducing in character.

Flame temperature is easily calculated by striking a balance between the heat of combustion and a function of the specific heat of the products of combustion, the volume of the product of combustion and their increase in temperature, the latter being substantially the flame temperature. Combustion in air requires that for each volume of oxygen consumed, roughly four volumes of inert nitrogen must be heated to flame temperature. Flame temperatures of gaseous combustions in air are relatively low, around 3000° F., and such flames are inadequate for the rapid local heating of metals.

By using oxygen, flame temperatures as calculated by the above heat balance would be in the order of 10,000° F., were it not for the fact that above 3000° F., such ordinarily combustible gases as hydrogen and carbon monoxide are increasingly difficult to combine with oxygen. Thus, the reaction of hydrogen and oxygen to form water not only is incomplete, from which follows that only a portion of the heat of combustion of hydrogen is liberated, but the normally stable hydrogen molecule is broken into its atoms in a reaction absorbing heat from the flame and limiting its temperature.

In Fig. 1, the percentage decomposition of the reaction products of common gaseous combustions, carbon monoxide, carbon dioxide, water vapor and molecular hydrogen are given for temperatures from 3000–7000° F. and for partial pressures of 0.1 and 1 atmospheres.

The higher the temperature and the lower the percentage of any constituent in the flame composition, expressed as the partial pressure of that constituent in the flame, the greater the percentage decomposition of its combustion product and conversely, the smaller the percentage of it that will unite with oxygen and liberate heat of combustion to increase the flame temperature. Increasing the oxygen content of the flame by increasing the ratio of oxygen to fuel gas fed to a torch, decreases the dissociation of the combustion products and liberates more of the heat of combustion. However, a point is soon reached where this extra heat of combustion is insufficient to heat the oxygen added to flame temperature and further oxygen additions actually cool the flame, the flame meanwhile becoming increasingly oxidizing in character to the point where it is useless for steel welding.

Gases such as hydrogen and the saturated hydrocarbons methane, ethane and propane, major constituents of city gas, natural gas and the petroleum distillates, when completely burned with oxygen give maximum flame temperatures in the order of 5000° F., at which point they are extremely oxidizing in character. To maintain a reducing atmosphere with these gases, a lower oxygen gas ratio must be used which reduces their flame temperature to a point where they are uneconomical for welding the higher melting metals because of their very slow rate of heating. The unsaturated hydrocarbon, acetylene, whose commercial availability marked the beginning of the modern technique of gas welding, has the property of generating an extremely high temperature, in the order of 6000° F., in a reducing atmosphere, offering at once the advantage of high speed of operation, dependent on high flame temperature, high flame luminosity (increasing the rate of heat transfer by radiation), high flame speed (increasing the rate of heat transfer by conduction), and the ability to produce unoxidized weld metal of considerable ductility.

Acetylene is known chemically as an endothermic compound. In its manufacture from calcium carbide, formed at high temperatures in the electric furnace, it

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† Assistant Manager, Applied Engineering Department, Air Reduction Sales Co.

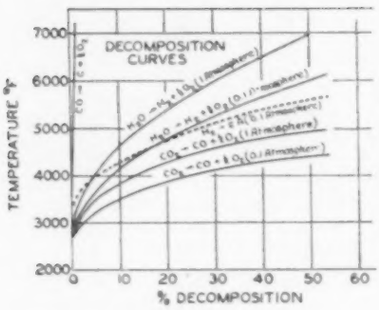


Fig. 1

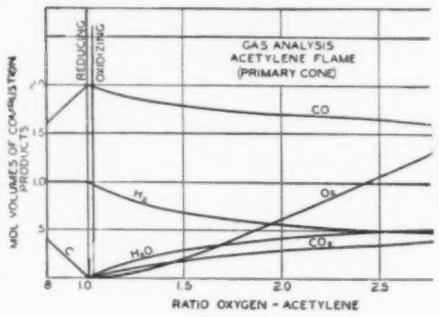


Fig. 2

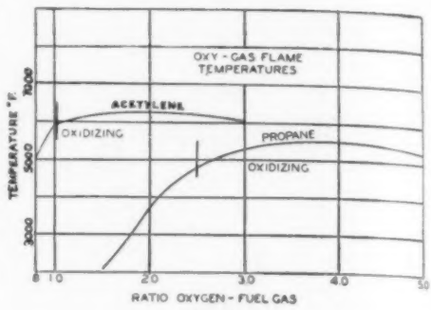


Fig. 3

has absorbed energy in its molecular structure, which can be released without combustion by the break-up of this structure into its constituent elements. The heat of combustion of the carbon and hydrogen in a cubic foot of acetylene is 1205 B. t. u., the endothermal heat is 228 B. t. u., the combined value of 1433 B. t. u. per cubic foot being the commonly quoted heat of combustion. A saturated compound such as propane may be calculated to have a heat of combustion of its constituent carbon and hydrogen of 2475 B. t. u. per cubic foot. On combustion, however, only 2309 B. t. u. can be liberated, 166 B. t. u. being absorbed in breaking up the compound which is therefore known chemically as exothermic. The effect of the endothermal heat of acetylene is to preheat the products of the molecular decomposition to a temperature of roughly 2000° F., from which point a further increase in flame temperature is produced by the partial liberation of the heat of combustion. Very high temperatures can thus be produced with acetylene, at low ratios of oxygen to acetylene. With saturated hydrocarbons which absorb some of the heat of combustion, a more complete combustion is necessary to develop a high flame temperature, resulting in an oxidizing flame.

In Fig. 2, the gas analyses of the primary combustion cone of the oxyacetylene flame are given for varying mixing ratios of oxygen to acetylene. The flame is strongly reducing below an oxy-gas ratio of 1.05 to 1, and shows little free oxygen at ratios as high as 1.2 to 1.

In Fig. 3, a comparison of the flame temperatures of oxyacetylene and oxy-propane at varying oxygen fuel gas mixing ratios is shown. At no point is the propane flame strongly reducing and above a mixing ratio of 2.5 to 1, the flame is strongly oxidizing. A comparison of the flame temperatures corresponding to the reducing flame state for the oxyacetylene and oxy-propane flames indicates the reason for the preeminence of acetylene over other available commercial gases for welding. Sporadic attempts are made to use gases other than acetylene for welding because of their cheaper prices per cubic foot. The reason for the failure of such experiments is due to inherent differences in the physical properties of these gases as indicated above.

The oxyacetylene flame, as commonly used for welding, is produced from a mixture of one volume of oxygen and one volume of acetylene. The combustion products of this mixture as seen from Fig. 2 consist of carbon monoxide which is very slightly dissociated into carbon and oxygen, and hydrogen which is undoubtedly considerably dissociated into its atoms. This combustion takes place in a very narrow cone surrounding the exit orifice of the welding tip and produces a temperature of roughly 6000° F. at that point. An intensely luminous blue cone results which is the active principle of the flame. The carbon monoxide and hydrogen, leaving this cone, combine with air oxygen (accompanied by its inevitable nitrogen) and produce a voluminous low temperature flame surrounding the active blue cone, commonly called the sheath flame. Due to its low temperature, the sheath flame is of secondary importance to the blue inner cone. By varying the ratio of oxygen to acetylene, the inner flame can be made more strongly reducing or more oxidizing in character. Oxyacetylene ratios as low as 0.97 to 1 are used for backhand or "speed" welding on pipe. Oxidizing ratios up to 1.2 to 1 are used for certain brass and bronze welding operations. The oxyacetylene flame is thus capable of producing a temperature of over 6000° F., coupled with extraordinary flexibility in regard to the oxidizing or reducing properties of the flame.

Part II—Practical Application of the Oxyacetylene Flame

The practice of oxyacetylene welding consists in melting the adjacent surfaces of the pieces to be joined, by application of the intense heat of the blue inner cone of the flame, forming a molten pool of metal, connecting these surfaces, which on solidification constitutes the weld. The variety of welding procedures for specific metals and applications is naturally too great to be encompassed in detail in the present discussion. However, it is possible to break down such procedures into a few broad classifications.

(*a*) *Welding without Filler Rod.*—Light gage metals are joined by melting adjacent surfaces, the resulting molten pool forming the weld metal which has the same composition as the base metal. Where weld reenforcements are required, additional weld metal is obtained by flanging the adjacent edges which are melted to form the weld.

(*b*) *Welding with Filler Rod.*—On heavier sections (over $^1/_{16}$ in.), additional weld metal is obtained from a filler rod (welding rod) which is melted in the pool formed by melting adjacent surfaces. Metals under $^1/_4$ in. in thickness are usually welded without preparation of the edges. Above $^1/_4$ in., the adjacent edges are beveled to form a vee, usually including an angle of 90°, to insure proper fusion of the bottom or root of the weld.

(*c*) *Forehand Welding.*—Forehand or "puddle" welding consists (for right-hand welders) in holding the torch in the right hand, welding rod in the left hand, inclined at a 45° angle to the right, and welding from right to left. The flame is directed away from the deposited weld metal and preheats the welding vee ahead of the welding pool. The walls of the vee are melted to a considerable extent and the welding rod used to agitate the welding pool (puddling) to assist in bringing any oxides formed to the surface of the weld. Fluxes are required with certain metals to assist in removing oxide films from the surface of the welding vee which would prevent the union of base and weld metal.

(*d*) *Backhand or "Speed" Welding.*—This is accomplished with the same torch and rod position by welding from left to right. The flames play on the weld metal

already deposited. A slightly carburizing flame is used in steel welding with this technique. The walls of the welding vee are brought to a sweat heat, but are not broken down as in forehand welding, the operation being analogous in some respects to brazing in that the weld metal is caused to wet the sides of the welding vee and little or no "puddling" of the welding rod in the weld pool is necessary. This method is extensively used in pipe welding.

(*e*) *Upward Welding.*—In this technique, the pieces to be joined are placed in a vertical position without beveling and spaced at one-half the plate thickness. The torch is held normal to the line of weld and a hole melted between the plates to be joined. By gradually elevating the torch, the adjacent weld surfaces are melted and flow downward filling the hole previously formed. The hole is thus gradually chased up the line of weld until the weld is completed. Two torches can be used, one on either side of the weld for welding thick plates by this method.

(*f*) *Multipass or Single-Pass Welding.*—Oxyacetylene welds are generally made using a single pass technique, the total volume of weld metal and reenforcement being laid progressively along the line of weld. For heavy plate (over ½ in.) and high-pressure piping, a multipass technique has recently been developed in which the weld metal is deposited in two or more passes along the line of weld. Reduced grain size and increased ductility are obtained in the deposited weld metal as compared with single-pass welding.

(*g*) *Automatic Welding.*—By using water-cooled multiflame welding tips, having as many as thirty or more small flames playing along the line of weld, oxyacetylene welding can be made fully automatic for production welding. Extensive use is made of this process in fabrication of pipe and tubing. The welding tip is positioned along the line of weld, the pipe or tubing preformed to a circular section from strip is moved automatically past the tip, the weld surfaces being heated to fusion to form the weld when pressure is applied by welding rolls immediately following the welding tip.

Oxyacetylene welding processes are thus characterized as automatic or manual, forehand, backhand or upward, with or without filler rod and single pass or multipass.

Part III—The Fundamentals of Oxyacetylene Cutting

All metals react with oxygen to form oxides, a process involving the liberation of considerable heat. In the case of steel, the oxide thus formed Fe_3O_4 has a melting point considerably below the melting point of steel and can be removed by the application of heat, thus exposing fresh steel surface to further oxygen attack. At temperatures below 1500° F., the rate of oxidation of a steel surface is so slow that insufficient heat is generated by the reaction of oxygen and steel to melt the oxide formed and the reaction ceases. Above 1500° F., (the ignition point of steel), sufficient heat is generated to melt the oxide exposing clean surface to further oxygen attack and to preheat the steel immediately behind the cut surface to the ignition temperature. The reaction then becomes self-sustaining and will continue as long as fresh oxygen is applied to the steel surface.

The chemistry of the steel cutting reaction involves the union of one pound of iron with 0.382 pounds (4.61 cu. ft.) of oxygen, generating 2870 B. t. u. of heat. In actual cutting practice, the iron removed from the path of cut is not entirely consumed by the oxygen jet, some 30 to 40 per cent being removed as molten metal washed from the path of the cut by the eroding action of the oxygen jet, moving, at a speed approaching that of sound. The oxygen consumption per pound of steel removed in the kerf is thus 30 to 40 per cent less than the theoretical figure quoted above.

The heat generated by the iron-oxygen reaction of the surface of the cut must therefore be sufficient to bring the steel beneath the reaction surface to fusion. This narrow zone of molten steel is mechanically eroded by the action of the oxygen jet, leaving a chemically unaffected steel surface exposed after cutting ceases. This is manifested by the bright surface, free of oxide or decarburization as shown by microscopic examination of the area adjacent to the cut, and explains why oxygen cutting has no chemically detrimental effect upon the steel cut.

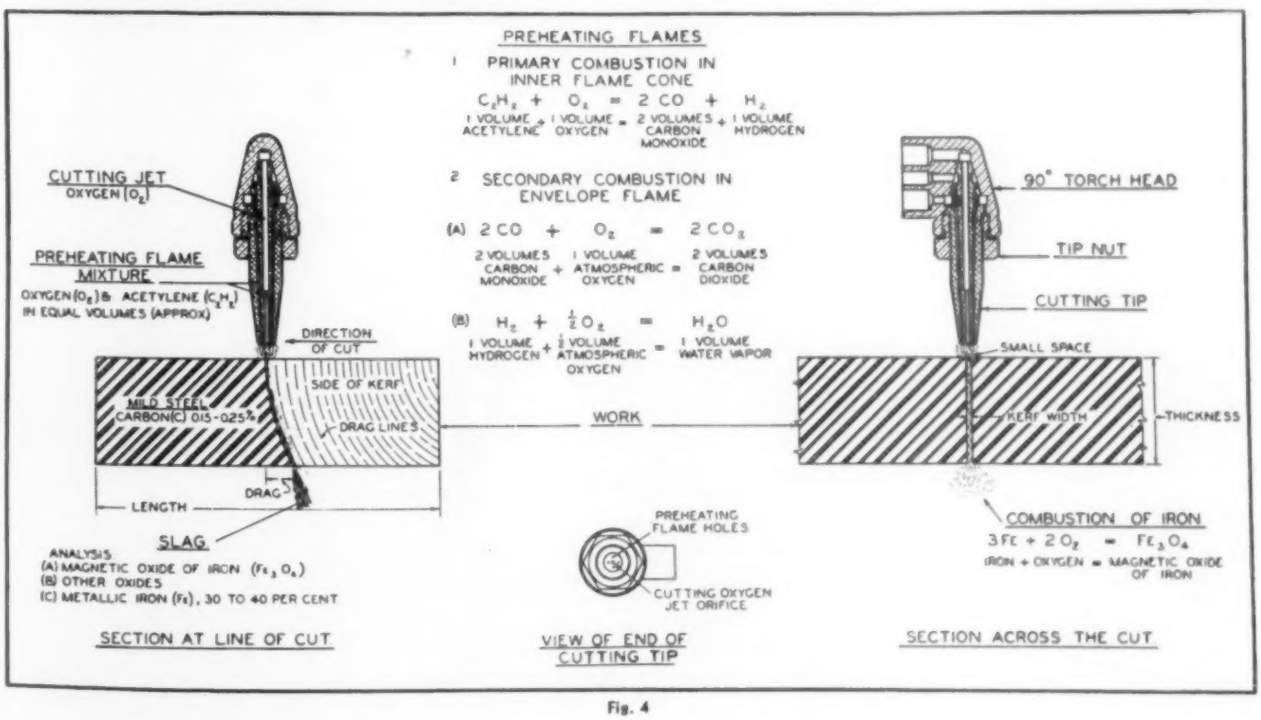

PREHEATING FLAMES
1 PRIMARY COMBUSTION IN INNER FLAME CONE
$C_2H_2 + O_2 = 2CO + H_2$
1 VOLUME ACETYLENE + 1 VOLUME OXYGEN = 2 VOLUMES CARBON MONOXIDE + 1 VOLUME HYDROGEN
2 SECONDARY COMBUSTION IN ENVELOPE FLAME
(A) $2CO + O_2 = 2CO_2$
2 VOLUMES CARBON MONOXIDE + 1 VOLUME ATMOSPHERIC OXYGEN = 2 VOLUMES CARBON DIOXIDE
(B) $H_2 + \frac{1}{2}O_2 = H_2O$
1 VOLUME HYDROGEN + ½ VOLUME ATMOSPHERIC OXYGEN = 1 VOLUME WATER VAPOR
CUTTING JET OXYGEN (O_2)
PREHEATING FLAME MIXTURE
OXYGEN (O_2) & ACETYLENE (C_2H_2) IN EQUAL VOLUMES (APPROX)
DIRECTION OF CUT
SIDE OF KERF
DRAG LINES
MILD STEEL CARBON (C) 015-025%
DRAG
LENGTH
SLAG
ANALYSIS
(A) MAGNETIC OXIDE OF IRON (Fe_3O_4)
(B) OTHER OXIDES
(C) METALLIC IRON (Fe), 30 TO 40 PER CENT
SECTION AT LINE OF CUT
PREHEATING FLAME HOLES
CUTTING OXYGEN JET ORIFICE
VIEW OF END OF CUTTING TIP
90° TORCH HEAD
TIP NUT
CUTTING TIP
SMALL SPACE
WORK
KERF WIDTH
THICKNESS
COMBUSTION OF IRON
$3Fe + 2O_2 = Fe_3O_4$
IRON + OXYGEN = MAGNETIC OXIDE OF IRON
SECTION ACROSS THE CUT

Fig. 4

Assuming that 65 per cent of the iron removed from the kerf is oxidized to Fe_3O_4, the heat generated by the reaction is equal to 1865 B. t. u. per pound of metal removed. Considering this heat liberation as compared with the heat required to raise the steel temperature to the kindling point, (228 B. t. u. per pound), it would appear that sufficient heat is available to preheat the metal along the line of cut to ignition temperature and that the cut once started would continue indefinitely. In practice, however, the top surface of the steel to be cut is covered with a protecting layer of mill scale or rust which must be removed by melting before reaction can proceed downward through the steel section so that heat must be supplied to the top surface by means of small oxyacetylene flames. These flames melt the oxide and preheat the steel surface along a given line of cut insuring direction and precision to the path of cut.

Figure 4 illustrates diagrammatically the chemistry of oxyacetylene cutting.

It will be noted that the point of exit of the oxygen stream from the underside of the cut lags behind the point of entry at the top surface. This horizontal displacement is called the drag and is a definite indication of cut quality reflecting at once too high a cutting speed or an insufficiency of oxygen. For scrapping cuts, where the object is merely severance of the piece, the drag is of small moment, and is in general quite large for economical cutting. In fine machine cutting, particularly in contour cutting with sharp changes in direction, small drag is required to prevent undercutting and to maintain a square cut surface.

The preheating flames are not subject to the severe requirements of the oxyacetylene welding flame, particularly, that they must be reducing in character, since oxidation of the metal at the surface of the cut is of no moment. In actual fact, the oxygen-acetylene mixing ratio in the preheating flames is generally around 1.3 to one and greater to take advantage of the higher flame temperature obtainable. The size of the preheating holes is varied depending on the cleanliness of the surface to be cut and cutting tips are designed with small preheating holes for use in machine cutting clean plate and with larger preheating holes for cutting scrap and heavily scaled material. In cutting cast iron or stainless steels very large preheating holes are used. Care must therefore be exercised in selecting the proper cutting tip for a given application. While the most generally used fuel gas for the preheating flames is acetylene, attempts have been made to substitute hydrogen, city gas or the petroleum distillates. The use of these substitute fuel gases is subject to the limitations previously discussed in connection with the welding flame, namely, slow rate of heating and increased oxygen consumption, resulting in a loss in economy as compared with acetylene practice.

The oxygen cutting jet issues from the cutting tip at an extremely high gas velocity in the order of 1000–1500 feet per second. Hilpert[1] has demonstrated visually that the form of this jet is considerably influenced by the cutting pressure and that for a given size of cutting orifice optimum cutting conditions are obtained over a fairly restricted range of pressures. For a given cutting orifice, an increase in cutting oxygen pressure beyond a given maximum results in a decrease in cutting quality. Crowe and Deming[2] have shown experimentally that cut quality as measured by the length of drag is dependent on cutting orifice size, the cutting speed and the volume of cutting oxygen. Figure 5 illustrates the relation of

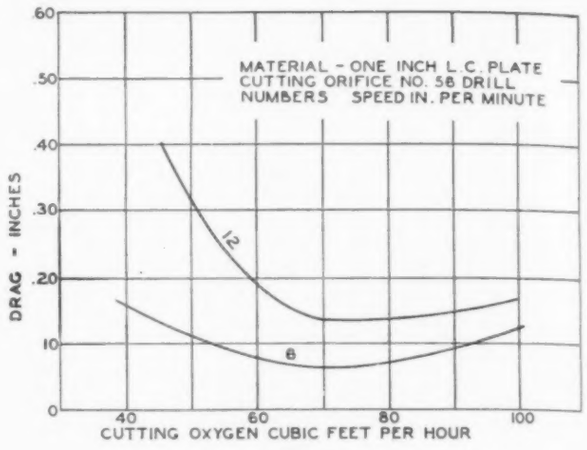


Fig. 5

cutting oxygen consumption (a measure of the velocity of the cutting jet), cutting speed and drag obtained in cutting one-half inch low-carbon plate with a No. 56 Drill cutting orifice. With a speed of six inches per minute, an increase in oxygen to the cutting jet from 40 to 70 cubic feet per hour resulted in a reduction in length of drag from 0.17 to 0.05 inches. Increasing cutting oxygen beyond 70 cubic feet per hour resulted in a decrease in cut quality, as measured by the drag, due presumably to increasing deformation of the cutting jet. Increasing the cutting speed to 12 inches per minute, increased the drag for any oxygen volume and also increased the lowest obtainable drag from 0.05 to 0.12 inches. High quality cutting thus requires a careful selection of the proper cutting orifice size, cutting oxygen volume and cutting speed depending on the thickness of material to be cut. Suitable cutting tables are obtainable from the manufacturers of cutting equipment and serve as a useful guide to correct cutting practice. Figure 6 will illustrate such a chart.

Machine Cutting Table

Steel Thickness Inches	Tip Drill Size	Gas Pressure Lb. per Sq. In. Oxygen	Gas Pressure Lb. per Sq. In. Acetylene	Cutting Speed Inches per Minute	Cutting Speed Feet per Hour
1/4	62	30	3	20	100
3/8	56	30	3	19	95
1/2	56	40	3	17	85
3/4	53	40	3	15	75
1	53	50	3	14	70
1 1/2	51	50	3	12	60
2	44	50	3	10	50
3	40	50	4	8	40
4	40	60	4	7	35
5	35	50	5	6	30
6	35	55	5	5	25

Fig. 6

The function of oxyacetylene cutting as a manually operated roughing out or scrapping tool is rapidly changing to that of an automatic finishing tool cutting steel shapes to a predetermined contour and leaving finished cut surfaces suitable for the application of weld metal without further preparation. Machines have been developed to carry the torch along the cut contour at a variable speed of from two to thirty-six inches per minute, to suit the thickness of material to be cut. Figure 7 shows a machine adapted for straight line or circle cutting. In cutting straight lines, this machine operates on a machined track. In cutting circles, as in the illustration, a radius rod and center-point are attached

[1] Investigations on Phenomenon of Arc Welding and Gas Cutting by Slow Motion Pictures, A. Hilpert, AMER. WELDING SOCIETY JOURNAL, July 1933.

[2] Effect of Tip Sizes and Pressures upon the Economy of Cutting—29th Annual Convention, International Acetylene Association, Chicago, November 12–14, 1928.

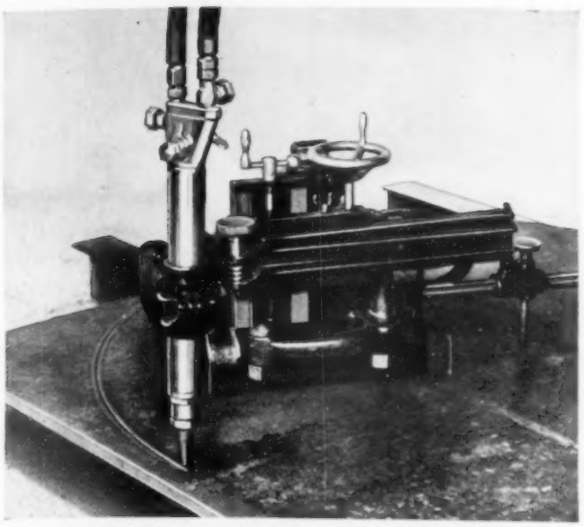


Fig. 7—Radiograph with Radius Rod and Center Point Equipped with Two Torches for Simultaneous Cutting

to the machine which is caused to travel about the center point. By combination of straight lines and circles of varying radii, fairly complicated contours can be cut with this portable machine. A machine combining an electrically driven tracing wheel and torch mounted on pantagraph arm allows of cutting irregular contours by guiding the tracing wheel along a cut line indicated on a blueprint. Incorporating a magnetic or mechanical template follower with such a machine permits of guiding the torch fully automatically along the contour of a previously cut cam. Multiple torch operation has been used for simultaneously cutting four pieces for each revolution of the tracing wheel or cam follower. A continuous development in machines for oxyacetylene cutting and in cutting technique is in progress, spurred by the increasing application of machine cutting to the problem of steel fabrication. The combination of machine cutting of rolled sections with fabrication by gas or electric welding has considerably altered construction technique in many industries, particularly where weight saving is an important factor and faces a future of rapidly expanding application.

Braze Welding a Guillotine Shear Frame

By R. B. KELLER†

A CRACKED cast-iron guillotine shear frame, 8 inches by 10 inches cross section in the crack was prepared for braze welding, as shown in Figs. 1 and 2, which also show the firebrick pillars laid up to support the frame and the beginnings of the brick preheating furnace that was laid around it.

The preheating furnace was laid up, as shown in Fig. 3, and covered over with corrugated sheet iron. Openings were provided of course through which the operators could make the weld and observe the progress of the job. The casting was heated with charcoal.

All welding was done in the position shown. Work started at 8 A.M. and continued until 9:30 P.M., actual welding time being 7¾ hours. A total volume of 870 cubic feet of oxygen and equal volume of acetylene were used; also 70 pounds of one-quarter inch manganese bronze rod and 2 pounds of brazing flux.

When the job was completed the furnace was refired with charcoal, covered over and left to cool down slowly. Due to the peculiarity of the casting shape, the operators found it quite difficult to reach one part, but finally succeeded by working in difficult positions.

†Pittsburgh Office, Air Reduction Sales Co.

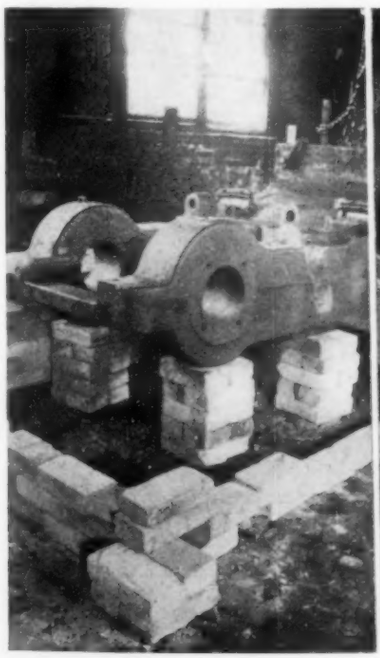


Fig. 1—Cracked Guillotine Shear Frame Prepared for Braze Welding

Fig. 2—Close-Up of Braze Weld Vee and Brick Support

Fig. 3—Braze Welding the Frame in Brick Charcoal-Fired Furnace

New Foreign Welding Standards*

By G. E. CLAUSSEN†

HOLLAND (*Laschtechniek*, **3** (1), 11–18, Jan. 1937). The main committee for Standardization in the Netherlands has issued five tentative standards for criticism, which must be presented before June 1, 1937. They are:

V 550 and 551—Qualification of Welding Rods. Tests for welds to be used in steel bridges.

V 658—Calculation of butt welds in boilers and pressure vessels.

V 659—Design of fillet welds.

V 663—General specifications and suggestions for welding in shipbuilding.

The material envisaged in the standards is low-alloy steel (not containing chromium) with 0.18 C Maximum, 0.04 P, to be used in conjunction with heavy coated electrodes.

V 550 and V 551—Mechanical Properties.—Heat treating or peening the specimens is not allowed. Six tests are required; two specimens each for tests 1, 2, 3 and 6.

1. Tensile test of all-weld-metal specimen. The tensile strength must be between 57,000 and 78,500 psi, the difference between the two specimens being not more than 7100 psi. Elongation must be not less than 25% (standard tensile specimen of the Netherlands).

2. Tensile impact test on all-weld-metal for structures subjected to impact loads, Fig. 1. A 540 ft.-lb. machine is used. The impact value must be at least 80 mkg./cm.², equivalent to 370 ft.-lb. Elongation in 2.36 in. must be at least 26%, reduction of area at least 40%.

3. Bend test on 90° V butt joint. Roller bend to 140°, free bend to 180°.

4. Tensile test on vertical-welded double T (cruciform) joint.

5. Tensile test on symmetrical, double strap, side fillet joint.

6. Fatigue test on 90° V butt joint, Figs. 2 and 3, for structures subjected to fatigue. A constant bending moment, rotating bend machine (Schenck type) must be used. A length of 3.15 in. must be subject to constant bending moment. At least 5×10^6 cycles at a stress of at least 27,000 psi must be withstood.

V 658 Calculation of Butt Welds in Boilers and Pressure Vessels.—The strength of the weld must not be assumed greater than that of base metal nor greater than 64,000 psi. Stress is calculated by the formulas $S = \frac{100P}{VA} \leqq \frac{T}{X}$

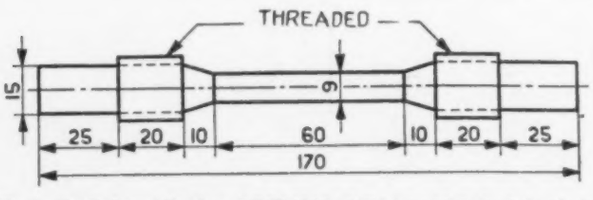


Fig. 1—Tensile Impact Specimen All-Weld-Metal (Tentative Netherlands Standard) Dimensions in Millimeters

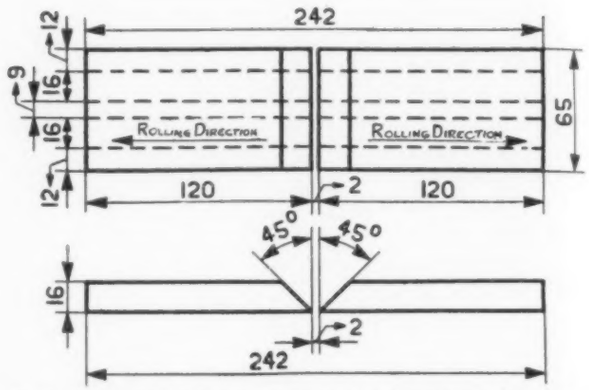


Fig. 2—Preparation of Plates for Rotating-Bend Fatigue Test of Welded Joints (Tentative Netherlands Standard) Dimensions in Millimeters

where P = load per mm. of weld
V = percentage decrease in effective thickness of base metal due to weld
A = thickness of base metal
T = tensile strength of weld metal
X = safety factor

The values of V and X are given in Table 1.

Table 1—Design Constants for Pressure Vessels (Holland)

Item	Quality of Weld A (Usual Welding)	Quality of Weld B (Made with Special Care)	Remarks
V	60	80	Not heat treated
V	70	90	Heat treated
X (boilers)	9	..	Not reverse welded
X (boilers)	7	4.5	Reverse welded
X (pressure vessels)	8	..	Not reverse welded
X (pressure vessels)	6	4	Reverse welded

By heat treatment is meant annealing above the upper critical.

V 659 Design of Fillet Welds.—The stress method is used rather than the load per linear inch. The inclination "a" of the line of action of the load to the critical section of the weld (throat) is the basis of calculation, assuming that the Huber-Hencky relation applies:

$$T_a = \frac{T}{\sqrt{\text{SIN}^2\, a + 3\,\text{COS}^2\, a}}$$

in which T_a is the allowable stress in the fillet weld and T is the resistance of the weld metal to normal stress (tensile strength, $a = 90°$). In pure shear $T_a = 0.58\,T$ and for values of "a" intermediate between 0 and 90° values of the ratio T_a/T are given. Since "a" is usually difficult to determine, the angle "b" made by the normal stress surface with the face of the weld is assumed related to "a," and design factors deduced therefrom. The tests by N. C. Kist and the ideas of the German standard DIN 4100 are adopted.

* Abstract and Translation.

† Research Assistant, Fundamental Research Committee, Engineering Foundation.

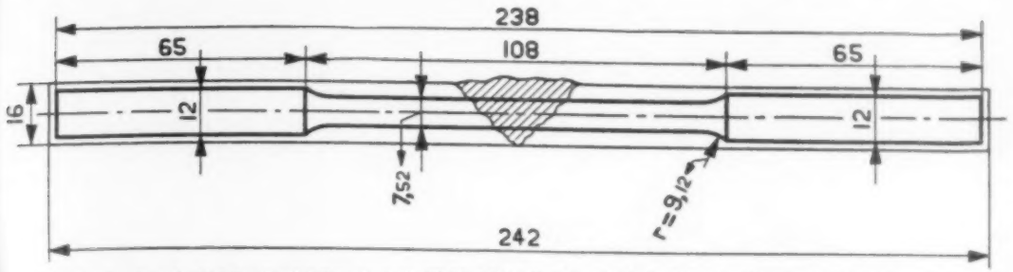


Fig. 3—Specimen for Rotating-Bend Fatigue Test of a Welded Joint (Tentative Netherlands Standard) Dimensions in Millimeters.

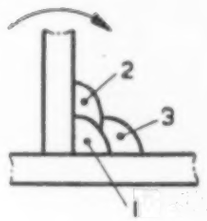


Fig. 4—Fillet Break Specimen (Tentative Netherlands Standard)

V 663 Welding in Shipbuilding.—The steel should contain no chromium and 0.18 C max., 0.04 P max., 0.05 S max. Crossing of one weld bead over another should be avoided. Welds in fatigue conditions should make an angle of not less than 45° with the direction of stress to develop maximum fatigue resistance.

Examination of fracture is made on specimens shown in Fig. 4 made in three passes in horizontal, vertical and overhead positions. The fracture is examined for homogeneity of weld, slag inclusions, penetration and structure.

FRANCE (*Rev. Soud. Autog.*, **28**, (273), 2–3, Dec. 1936). The first draft of a specification for coated electrodes for structural steel has been issued by the French Committee for Welding Standards. Eleven diameters (0.04 to 0.51 in.) and four lengths (6 to 18 in.) are standardized. Four standard colors are given to electrodes according to their mechanical properties, as shown in Table 2. The mechanical properties are determined on all-weld-metal specimens machined from a deposit made in an angle iron 10 in. long. The speed of welding must be such that the corners of the angle iron do not become red.

Table 2—Standard Colors and Properties of Covered Electrodes (France)

	Mechanical Properties of Metal Deposited in a Horizontal Plane				
Code No.	Tensile Strength psi	Elongation % $L = 7.2d$	Impact Value Charpy, Mkg./-Cm.²	Brinell Hardness	Standard Color Applied to Bare Ends and Cartons
E 40	54,000	15	2	120	red
E 50	68,000	20	6	150	yellow
E 60	82,500	15	8	170	blue
ER 70	97,000	5	2	220	black

ENGLAND *B.S.S.* No. 709, Nov. 1936. Methods of Making a Cold Bend Test on Fusion Welded Joints.

The specification describes the factors affecting the bend test for welds. It also describes two bend tests for determining the ductility of weld metal, and two bend tests for determining the ductility of a welded joint.

Summary of Report of Welding Research Committee of the Institution of Mechanical Engineers, Great Britain*

1. The analyses of weld metal show that the carbon and manganese contents of the metal in the weld may differ very considerably from those in the electrode.

2. If a sufficient amount of top metal is laid over the "V" of weld metal connecting two plates, the metal within the "V" may become normalized to an appreciable depth and a large portion of the weld may therefore have a normal microstructure.

3. Small cavities and inclusions may be found in all except the best welds and these may have an important effect upon the fatigue range of the weld. X-ray examinations of the weld can show the location, size, number of cavities and inclusions.

4. The resistance to creep of weld metal is about the same as that of very mild steels. At temperatures above 300° C. the phenomenon of creep may become of importance. At boiler temperatures as distinct from superheat temperatures no serious difficulty due to creep need be apprehended at the normal working stresses of boilers.

5. The results of the impact tests seem to show that at any temperature at which boilers containing weld metal of the particular qualities tested may be working, there is no fear of that type of brittleness which impact tests indicate causing failure. At temperatures below freezing point there is very little difference between the results from welds and from mild steel plates.

6. The investigation indicates the desirability of a bend test in which, in assessing the ductility of the weld metal, the percentage elongation of the weld metal at the surface of the "V" is measured.

7. Repeated stress tests on various types of machines show definitely that the welds examined have fatigue ranges less than the range for unpierced steel plates of the same tensile strength as the weld.

EDITOR'S NOTE. For example, unmachined 70° V Butt welds made with covered electrodes (shielded arc type, 0.10 C, 0.25 Mn) in $^1/_2$ in. structural steel (tensile strength about 62,000 psi; endurance limit 10×10^6 cycles = ± 34,000 psi in reversed bending) had an endurance limit of ±23,500 psi in reversed bending, as welded. The reversed bend endurance limit was from 300 to 3000 psi higher at 250 or 450° C. than at 20° C. Machining raised the reversed bend endurance limit up to 4000 psi, but heat treatment was of doubtful value.

8. The large number of welds that have been examined, some of which experiments are detailed in this report, show clearly that it is important to select a suitable type of electrode and welding technique for boiler work in order that cavities and inclusions should be reduced to a minimum. Further, definite control in the method of welding is of fundamental importance, particularly in order to avoid imperfect fusion.

9. The tests that have been carried out on a number of welds indicate that in the neighborhood of welds corrosion in a fluid of certain types is not likely to be more serious than the corrosion of the plate.

* Published in 1936 Proceedings of The Institution of Mechanical Engineers.

Economics of Welding and Cutting from a Cost Standpoint*

By GORDON G. HOLBROOK†

I HAVE been assigned this subject in the ninth of a series of lectures on the Fundamentals of Welding. Being neither an economist nor a welder, I approach such an ambitious topic with some misgivings. Practically my entire experience with welding has been in its development in the shipbuilding industry and I, therefore, will confine my remarks to this rather specialized application.

I will not risk boring you with a recital of tedious figures. I am aware that any detailed cost data are of real value only for the estimators in the plant where they are collected. We can, however, review some interesting steps in the development of welding and cutting in shipbuilding and, in general, indicate the effect of their use on the other trades employed in the construction of a steel vessel. We will also outline a few of the problems to which welding in ship construction gives rise and will discuss some of the methods being employed toward their solution.

Flame cutting was first in common use in the shipyards about 1912 and a few years later electric welding was introduced, using the early type of alternating current machines. Up to 1919 or 1920, welding was used principally as a corrective measure to build up plate edges or weld unfair rivet holes. Flame cutting, in general, supplanted mechanical cutting for airport holes, door openings and the like and the gas torch also came into general use for heating to assist in fitting up rolled or furnaced plates during construction, replacing the oil torch.

The earliest production welding the speaker can recall was in 1917 and was employed in fastening clips for securing built-in metal furniture on the platform decks of the War Program destroyers. Flame cutting and electric welding were also used in the manufacture of the boat davits from rolled H sections for the same vessels. The beams were split and tapered by flame cutting and were then welded along the neutral axis after being bent to shape. This method provided davits of much greater strength and less weight than was possible with the old solid round type. Watertight staples and collars were built up by welding, supplanting the fire-welded product on both naval and merchant vessels. Rail stanchions, pipe hangers and miscellaneous fittings were soon fastened by welding. In those earlier days, equipment and technique were still rather crude and the welders themselves were frequently poorly tairned and supervised. Failure of some of the welding in service caused a feeling of skepticism on the part of both the builder and owner and did much to retard the rapid application of welding in ship work.

About 1927 several designs for building small welded craft came forward. Time will not permit the description of these various types or a discussion of their relative merits. Many sand, coal and garbage scows, oil barges, lighters and small self-propelled vessels have been built at prices which rapidly eclipsed the cost of riveted craft for the same service. They also entered into the field hitherto dominated by wooden construction with the obvious advantage of maintaining lifting capacity throughout their life. Many of these small craft have been constructed in yards which had not previously done steel work, as the use of welding and flame cutting permitted them to be built without the use of expensive fabricating equipment. The experience gained in building these smaller vessels has been valuable to the shipyard, both in training personnel and suggesting design details which could be adapted to larger ships.

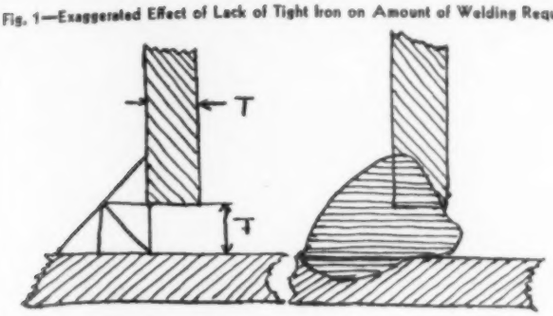
In the construction of larger vessels, welding was first used in the fabrication of hold pillars in the Panama Pacific liners built in 1927. The colliers "BERWINDVALE" and "BERWINDGLEN" had welded tank tops in 1928. Part of this welding was done by an automatic machine with deposited electrode. In 1930 the auxiliary machinery foundations and shaft alleys on the ill-fated "MORRO CASTLE" and her sister ship, the "EL ORIENTE," were built up of welded construction. Also in the same year, riveted plate tank tops on two bulk cargo carriers on the Great Lakes were replaced with channels automatically welded together.

In 1931, the Matson Line ships, "MARIPOSA", "MONTEREY" and the "LURLINE" had welded steel bulkheads in the quarters. In 1932, the four Grace Line ships, "SANTA ROSA," "SANTA PAULA," "SANTA LUCIA" and "SANTA ELENA" had welded hold pillars, auxiliary foundations, bulkheads in the quarters and miscellaneous details. About 19,000 pounds of welding rod were used on each of these Grace Line vessels. In 1935, the two tankers "R. P. RESOR" and "T. C. MC COBB" had welded main bulkheads, transverse frames and deck houses, also both main and auxiliary machinery foundations were welded. About 83,000 pounds of welding rod were used on each of these ships. At the present time, several shipyards are building partially welded large sized tankers, some of which have very novel features in design. At the Federal Shipbuilding and Dry Dock Company, we are making further progress toward supplanting riveted construction with welded design based on our experience gained on the four partially welded tankers now in active service.

In general, our experience in welding at Federal indicates that oil barges and similar small completely welded vessels can be constructed at lower cost than those of riveted design. In large oil tanker construction as noted above, we have built four vessels with sixty per cent of the normal number of rivets supplanted by welded construction and are now building four more in which the reduction in the number of rivets runs to approximately

* Presented at Ninth Evening Course Lecture of New York Section, AMERICAN WELDING SOCIETY, held Feb. 2, 1937 at Polytechnic Institute of Brooklyn.
† General Superintendent, Federal Shipbuilding & Dry Dock Company.

Fig. 1—Exaggerated Effect of Lack of Tight Iron on Amount of Welding Required



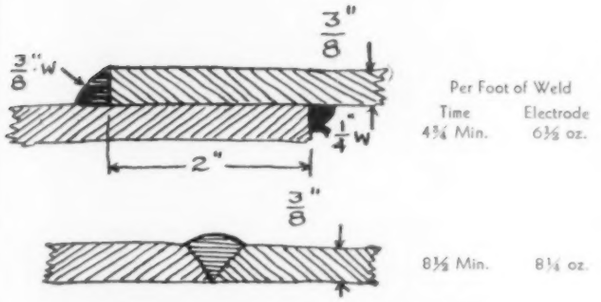


Fig. 2—Relative Cost of Making Lapped or Butt Joint

75 per cent. Outside of a saving in weight of steel of about ten per cent, there appears to be no definite reduction in cost at present. There is, however, a shift of methods and relative costs between trades which will be noted later (Fig. 5).

In the amount of steel ordered, the saving in weight is accomplished principally by the omission of bounding bars, faying flanges for riveting and the narrowing or elimination of laps of plating where welded seams are employed. In general, the specifications for steel suitable for riveting are applicable for use in welded construction. If flanged plates are designed in place of channel stiffeners, it is advisable to order cold flanging quality steel for these members if $^{7}/_{16}$ inch or more in thickness. This involves an extra cost of 15 cents per 100 pounds. Due to the buckling experienced in using large plated surfaces of welded construction in thicknesses below $^{1}/_{4}$ inch, it might be desirable to have such plating stress-relieved or normalized at the rolling mill. The code of Uniform Extras and Deductions published by the American Iron and Steel Institute, issued September 1, 1934, quotes an extra of 15 cents per 100 pounds for stress-relieving plates up to $^{5}/_{8}$ inch in thickness and having less than 0.30% carbon. It also quotes an extra of 50 cents per 100 pounds for normalizing plates up to the same thickness. It is not believed that the steel mills generally are as yet ready to offer this service unrestrictedly. When such heat treatment becomes available, however, it might be worthy of investigation. There are also available light weight beams and channels which are very well adapted for use as stiffeners in welded construction, where savings of weight are of prime importance.

The first operation in the yard in building a steel ship is the laying down in the Mold Loft of the lines of the vessel and the making of full sized templates for the various steel members. In proceeding from riveted to welded construction, several important changes in this work may be noted. In riveted construction, the exact location and size of all rivet holes are shown on the templates. In welded work, there are no holes located except tack holes for erection purposes. However, frame lines, water line planes or the vertical buttock planes must be located on the templates for purpose of regulation on the ship.

For ground assemblies, it is also necessary to make large shape molds for trimming the assemblies to the proper size after welding is completed. There is a trend toward using poles or strips for the lay-out of welded stiffeners, similar to the practice in many structural shops. This pole method may be extended to plating without roll or shape as the experience of the layer-out in the Plate Shop makes him more familiar with this method. It is not the practice to specify or locate welding on the templates as experience shows that the marks would be obliterated from the steel before the welding could be performed. In general, there does not appear to be any material change in cost in the Mold Loft as we go progressively into more extended use of welded construction.

The next step in the building of the ship is the fabrication of the steel from the Mold Loft templates in the Plate Shop. Here we note more radical changes in the operations. Much of the plating for ground assembly of welded work comes direct from the storage field to the assembly skids. Large areas of rail skids, heavy flush plating or cast-iron slabs must be provided to receive the welded work. The great number of flanged plate stiffeners which are called for in welded construction makes a large hydraulic press necessary. The press should have at least a 24-foot blade and be constructed so that flanged stiffeners up to 40 feet in length may be fabricated. A mangle roll or roller leveller is a very valuable tool for removing buckles from thin plating before abssemly or for straightening strips before flanging. With the relatively few number of holes required in welding or semi-welded plating, the table punch becomes of less value than formerly and small buggy drills may be used with economy in making the scattered holes. The saving of cost in punching, shearing and planing which is the feature of riveted work is just about balanced by the larger amount of hydraulic work in welded construction and the greater scope of ground assemblies. It is probable, however, that as we gain experience in lay-out, fabrication and ground assembly methods for welded construction, savings in the cost of fabrication up to 15 per cent or 20 per cent may be realized.

The erection, regulation and fitting of the ship comes next in order. As we employ more blank plates and framing members, special slings and clamps must be designed for erecting the steel, in place of the customary shackles through the rivet holes. Instead of matching up holes in regulation, use is made of the frame, water and buttock lines located on the members by the Mold Loft and re-established by chalk line after erection. Shores, jacks and turnbuckles are used for drawing the members together. Although it is often stated that tight faying surfaces are not essential in welded work, experience shows that they are extremely desirable in facilitating the progress and economy in the production welding.

The size and extent of the finished welding is marked on the steel members and the tack welding in place is performed. String welds of about $^{3}/_{16}$ inch in size and $1^{1}/_{2}$ to 2 inches in length are used to fasten the members in position. String welds are preferable to pea welds as they produce a weld of better strength and appearance when later covered by the finished welding. In intermittently welded connections, the tack welds should generally be made equal to the length of the finished increments. It is desirable to govern the rapidity of erection by the rate of following up with production welding. Too much steel should not be placed in position ahead of the

progress of welding, to avoid restraining the shrinkage of important members and the consequent building up of internal stresses. From a cost standpoint, the erection and fitting of the members in place may run up to 15 per cent or 20 per cent higher in welded construction than is customary in riveted work. This does not include tack welders' labor but does include fitters' time in the removal of the buckles and distortion which may appear in thin welded plating.

The tack welding, production welding, acetylene gas cutting and heating at the Federal Shipbuilding and Dry Dock Company are under the direction of a separate department. The tack welders and gas cutters are assigned to the use of the other departments requiring their services and the production welders work directly under the supervision of their own department. In the most recent tanker construction, the cost of labor in this department runs about equal to that for erection, regulation and fitting. As a higher proportion of welded work is undertaken, the cost of this part of the work will rise accordingly. In a tanker with only minor parts welded, this welding and gas cutting labor would be about 25 per cent of the erection figure.

The division of welding and gas cutting labor runs approximately 35 per cent for tack welding, 40 per cent for production welding, 15 per cent for production gas cutting and 10 per cent for heating. This ratio of tack welding to production welding is often not recognized by estimators and designers. On vessels of extremely light construction, the tack welding cost may even run in excess of the production welding figure, due to the greater difficulty of assembling thin members and holding them in place for production welding.

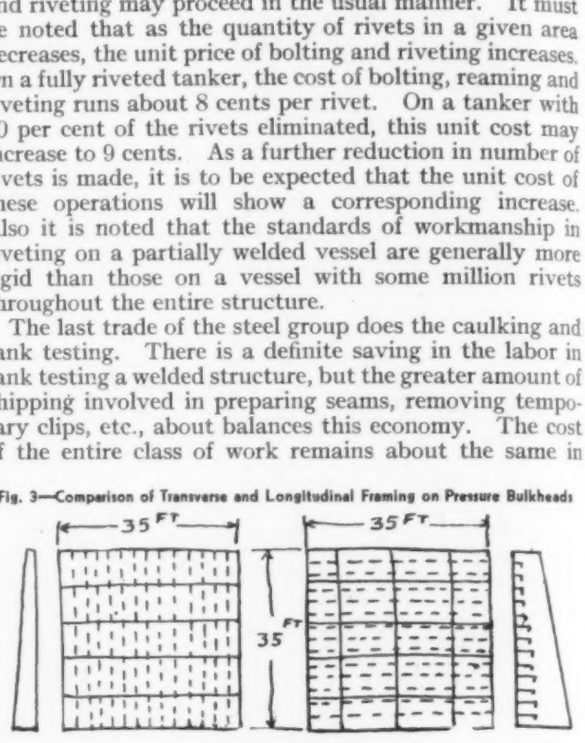
An average figure for the amount of electrode consumed by a production welder on merchant work in an 8-hour day runs about 25 pounds and 6 pounds for a tack welder. Experience generally indicates that the cost of labor on vertical welding is 25 per cent higher and overhead welding 50 per cent higher than in the flat position. An acetylene gas cutter in the ordinary course of a day's work used an average of $4.00 worth of acetylene and oxygen and when heating may consume up to ten times that figure. This high cost of materials is very often not recognized by shipyard supervisors in requisitioning the services of a heater or gas cutter. In many cases, it may be economical to use more effort and time on the end of a wrench than to call for a heater, or to drill or chip a hole rather than use flame cutting.

Designers are often carried away with the saving of weight in welded work by using flush butts in plating in place of lapped seams. It is possible to make a lap joint in $^3/_8$-inch material with a width of lap of about 2 inches employing a $^3/_8$-inch weld on the smooth side and $^1/_4$-inch sealing weld on the back side with $4^3/_4$ welding minutes per foot; using $6^1/_2$ ounces of electrode. If this joint were made up as a flush butt with 60 degree bevel and 25 per cent reinforcement, the welding time would be $8^1/_2$ minutes per foot in making the 3 passes needed and would consume $8^1/_4$ ounces of electrode. Furthermore, the labor in beveling and fitting up the flush butt is much greater than in the case of the lapped joint. There is also a greater tendency to shrinkage and distortion in the case of the flush butt. It is, therefore, difficult to justify the flush butt with the saving of only the $2^1/_2$ pounds per foot of extra steel which is in the lapped seam. It is true that a flush butt possesses the greater strength but its use should be confined to places where strength is a governing consideration (Fig. 2).

After all production welding in a given zone or area is performed, the next step in a partially welded design is to perform drilling, reaming and riveting. It is important that all of the welding be accomplished before any rivets are driven to avoid loosening up of the rivets by the shrinkage caused by welding in the same plane. It is a safe practice in a partially welded design with riveted seams and butts on the shell plating to develop the outside strakes of shell in the Mold Loft and drill through the inside plates on the ship. This drilling may be done full sized and produce a perfect match of holes. Bolting up and riveting may proceed in the usual manner. It must be noted that as the quantity of rivets in a given area decreases, the unit price of bolting and riveting increases. On a fully riveted tanker, the cost of bolting, reaming and riveting runs about 8 cents per rivet. On a tanker with 60 per cent of the rivets eliminated, this unit cost may increase to 9 cents. As a further reduction in number of rivets is made, it is to be expected that the unit cost of these operations will show a corresponding increase. Also it is noted that the standards of workmanship in riveting on a partially welded vessel are generally more rigid than those on a vessel with some million rivets throughout the entire structure.

The last trade of the steel group does the caulking and tank testing. There is a definite saving in the labor in tank testing a welded structure, but the greater amount of chipping involved in preparing seams, removing temporary clips, etc., about balances this economy. The cost of the entire class of work remains about the same in

Fig. 3—Comparison of Transverse and Longitudinal Framing on Pressure Bulkheads



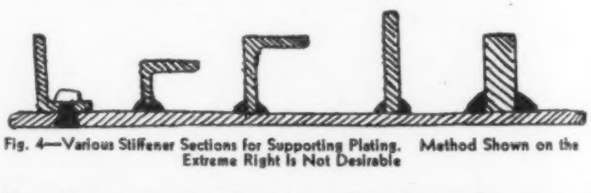


Fig. 4—Various Stiffener Sections for Supporting Plating. Method Shown on the Extreme Right Is Not Desirable

either riveted or welded work. There is another type of work which, while not strictly steel work, is much affected by the transition from riveted to welded construction. This is the work of shoring and fairing the ship, performed by the carpenters. More care must be exercised in keeping a welded ship well blocked and faired as the work progresses as there is less chance to pull the vessel into shape by using drift pins in the rivet holes. Also the checking-up on shrinkage and distortion and placing of ribbands on assemblies is a factor in the cost of this work, particularly in vessels of very light construction. The cost of such work has shown an increase of some 25 per cent as the extent of the welding has become more general.

In shipyard trades other than those directly concerned with the steel hull, welding and flame cutting are being utilized to an increasing degree with advantage both to workmanship and cost. Where wood decks are laid over a steel deck, studs have been welded to the steel deck for fastening the wood planks. These replace the old type of through bolts with nuts, washers and grommets under the deck. The same type of fastening is used in erecting

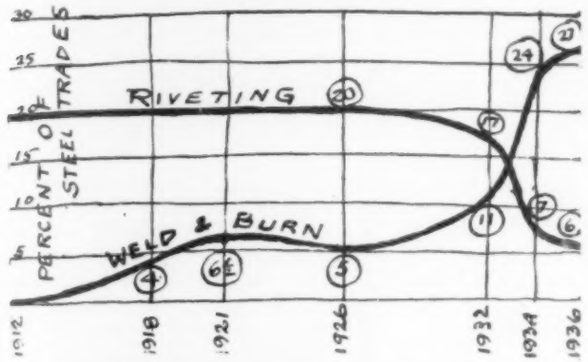


Fig. 5—Trend of Riveting and Welding Costs in Ship Construction

aluminum foil insulation against steel bulkheads or decks. Electric and gas-welded joints are frequently used in steam, water and oil piping and special tube turns have been developed for use in place of fittings. Pipe hangers generally are welded to the structure, using bolted connections to the piping where portability is desired. Several types of spuds or clips are in use for holding the straps for fastening electric wiring. These eliminate the drilling and tapping of the steel structure for the small brass screws commonly used, which were a frequent source of leakage. While devices such as those mentioned are of advantage, it is impossible to give any definite conclusions as to the saving in cost resulting from their adoption. It is noted that the welding labor on this miscellaneous work is included in the figures given before.

Truly enough, it is realized that the general statements given above do not indicate, so far, any very definite saving in cost in supplanting riveted with welded construction. This does not mean that such economies will not ultimately be realized. The problem in merchant ship construction is to keep the cost of new designs within the range of the standard riveted design. While owners are now recognizing some of the advantages of welding and are willing to accept new designs, competition renders it impossible to get a higher selling price for a welded ship than for one of riveted construction. Further progress toward all-welded vessels will continue to be made as the shipyards gain experience both in design and the solution of the manufacturing problems.

It may be of interest to review some of the new problems which become apparent in welded ship construction. The first fact encountered is that welding shrinks the members welded by an appreciable amount. The degree of shrinkage is more apparent in vessels of light construction than in those of heavier scantlings. The greatest shrinkage is caused by continuous welding at right angles to the direction of measurement. The shrinkage in the same direction as the line of welding is very much less than that in the transverse direction, which is one of the advantages of employing longitudinal framing in welded construction. Factors affecting this shrinkage are cooling stresses in the rolled steel, procedure in welding, current values used in the welding and the number of welders working together in a given area. It is generally believed that the greater the shrinkage observed in a welded structure, the less are the internal strains built up by the welding. In a partially welded tanker, the overall shrinkage in about 250 feet of length has been recorded as 2 inches. In vessels of very light construction, shrinkage of two or three times that amount has been observed in spite of current adjustments to the length of members to compensate for the shrinkage during construction. In vessels where the ends of the ship are largely of welded construction, a rising of the bow and stern from the keel blocks has frequently been observed.

It may be desirable to consider using an expanded scale in the Mold Loft on welded construction when the amount of longitudinal shrinkage becomes an important factor. On extremely light vessels, an expansion of $1/4$ inch in 10 feet is suggested. The rising of the bow and stern of the ship may be compensated for by setting the keel blocks somewhat lower at the ends of the ship and following up with the blocking as the structure rises. Some shipyards weld up the vessels in sections, leaving excess metal at the ends of these sections, making the closing weld between the sections last. This may partially overcome the shrinkage and warping of the ends but may also leave unfair areas in the shell and a concentration of stresses. It is expected that as our knowledge of the most desirable procedure of welding increases, part of this shrinkage and deformation may be avoided.

One problem, which is a direct result of the shrinkage and internal strains in the welded structure, is the local buckling of the plating between stiffeners and in some cases deflection of the stiffeners themselves. These conditions are more pronounced when the plating is less than $1/4$ inch in thickness. Mangling of the thinner plates before assembly often helps this condition. Light bulkheads and decks, however, often require fairing several times after their assembly and erection in the ship. Several methods of fairing buckles are used; employing heat either from an acetylene torch, carbon arc or bead of welding. Local spots may be heated with a torch and the metal upset into the heated spot by use of wooden mauls or hammers backing up the buckle with a plate and jack or shore. When the metal has been upset into the heated spot, it may be cooled or "set" with a fine jet of compressed air.

Another method involves heating spots about the size of a quarter with an acetylene torch, using a small tip and then immediately cooling with a jet of air and water. These spots are pitched about 2 to 3 inches apart and when the proper sequence is used, buckles may be removed without the use of hammer or jack. A third method consists of laying down a bead of welding in the buckled area and following up closely on the back side of the plate with a jet of air and water. This last method is quite simple and rapid but produces ridges in the plating and in many cases where the welding is exposed, the bead must be chipped off or ground smooth. On a complicated light welded structure where appearance is important, the cost of labor in fairing buckles has amounted nearly to one-half of the cost of the original productive welding.

The designer can help in the minimizing of this unproductive expense in fairing the structure by avoiding as much as possible plating $3/16$ inch and less in thickness and by selecting stiffeners of great sectional strength. The stiffening members should preferably run in the same direction and the use of continuous welding should be kept to a minimum. The welding of relatively thick stiffeners to thin plating should be avoided and butts of thin plating should belapped instead of flush (Fig. 4). If buckles are encountered, their removal should be left until the last possible stage in the completion of the work on the vessel so as to avoid repeating the fairing operation a second time.

The problem of building up man-power among the welders to take care of the increasing scope of the welding work in the shipyards, is an important one. Several shipyards on the Atlantic Coast have been employing up to two hundred or more welders at the same time. Many of the larger yards operate schools to train welders and thus are able to keep up with the demand. Our ex-

perience at Federal shows that it takes about two hundred hours of instruction to train an intelligent young man to weld sufficiently well to pass the United States Navy qualification test. After this test, it required from five to seven months' experience as a tack welder for the man to qualify for production welding. Some shipyards have made a practice of training helpers or mechanics in other trades as tack welders and then retain them in these departments. However, it is considered more desirable to select men who really want to become welders and give them the longer training necessary to become production welders, rather than take shipfitters or pipefitters and make passable tack welders of them.

The welding foreman must be supported by a corps of efficient leaders and inspectors. The welding supervisors have an important task not only in assigning the work for the operators, but also in seeing that the proper current values are used, the correct procedure followed and that the grade of welding is the highest. So far there is no acid test to apply to a finished weld to determine its quality. It is, therefore, very important to use the utmost care in the selection of men to be trained for welding; build up their pride of workmanship and ambition to advance; and check up the work as performed to see that it is properly executed.

The problem of protection of the eyesight of men working with the welder, can generally be solved by supplying them with colored goggles. The fumes attendant on the use of heavily coated rod give rise to a problem of ventilation, particularly when used on galvanized material. This ventilation can be accomplished by a flexible metallic hose led close to the arc and running to an individual exhaust fan or a main duct leading to a large capacity exhaust fan located on the deck of the shipway. In addition to the exhauster near the arc, a general exhaust fan may be used if the space is inclosed and other men are working in the compartment. Compressed air hoses have sometimes been used for ventilating purposes but the cooling effect of the expanding air and the smell of oil and rubber makes this method undesirable except as an emergency measure.

It may appear that these topics are digressing from the general subject, but they all have their effect directly or indirectly on the cost of performing the work. We have come a long way from the earlier days when welding was first introduced into the shipyards. Welding and flame cutting are here to stay and if we can continue the same rate of progress that we have made in the past ten years in the adoption of welding, the day of the fully welded ship should not be too far distant.

Fluxes—Their Function in Metallic Arc Welding*

By D. L. MATHIAS†

AS WE glance back over the past few decades, we find that the fabrication of metals has been revolutionized by the introduction of welding. Many processes are in daily use producing an almost endless variety of industrial and domestic articles and it is difficult to mention a single field in which welding has not played an important part. The most spectacular and most widely used process today is that known as metallic arc welding.

Through painstaking and unceasing research work, the engineer has developed the metallic arc process to a high degree of perfection. The powerful machinery of the modern ocean liner, the equipment of the vessels that guard our coasts, the high pressure stills that produce gasoline for automotive use, the power equipment for the streamlined train and the gates, penstocks and

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† Research Laboratories, Westinghouse Electric & Mfg. Co.

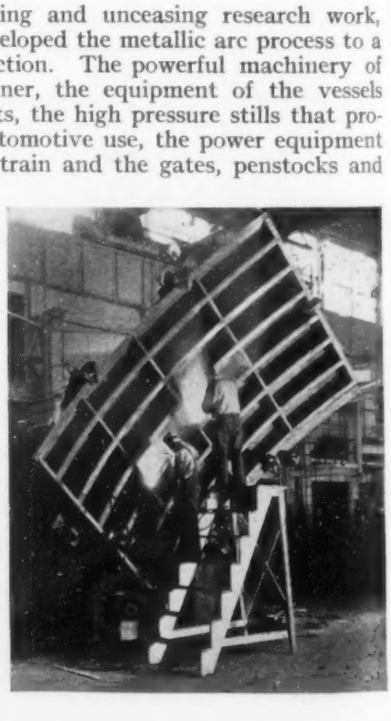
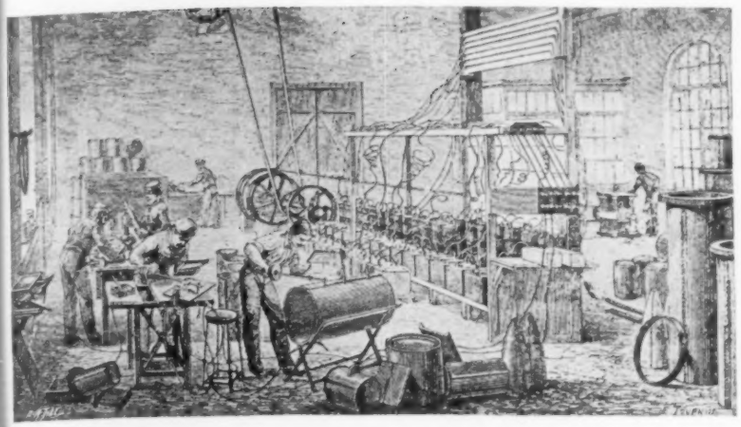


Fig. 1—(Left) Shop Assembly of One of Eight Arc-Welded Cylinder Gates for Use in the Intake Towers of Boulder Dam. Total Weight for Gate—510,000 Pounds

Fig. 2—Welding Ribs on a Segment of the Boulder Dam Cylinder Gates



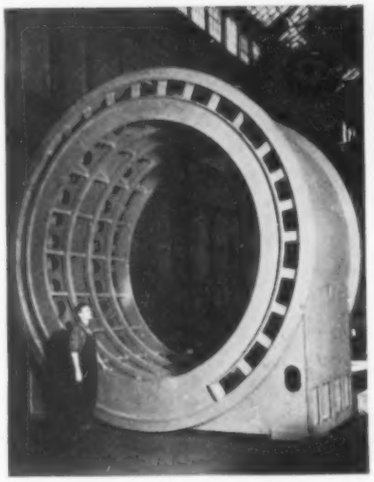


Fig. 3—Reproduction of an Old Wood-Cut Showing an Electric Arc-Welding Shop of the Year 1887
Fig. 4 (Right)—Stator Frame Section of 60,000 Kva. Hydrogen Cooled Frequency Changer Built for the City of Los Angeles

power generating machinery for such projects as Boulder Dam are outstanding accomplishments of arc welding. (Figs. 1, 2 and 4.)

Prior to the development of arc welding, casting, forging, riveting and bolting were the principal methods employed in the fabrication of metal structures but their limitations prevented the engineer from taking advantage of the economies of the large units, reduced weight and simplified production made possible by welding. Nor should we overlook the part that welding has played in the maintenance of equipment, for it was during the World War when all available facilities were required to keep a steady supply of materials moving to the men at the front that the real possibilities of welding were recognized through its successful application to the repair and construction of essential equipment.

Unlike other methods used to join the individual members of a structure, welding fuses the components together in such a manner that each becomes an integral part of the completed unit. As we watch workmen cut and form plates, structural shapes and bars into more or less intricate patterns and then weld them into sturdy structures, we are apt to pass over the matter lightly without reflecting upon the vast amount of pioneering and development that was required to bring welding to its present state of perfection.

Briefly stated, an electric arc is formed by current flowing across a gap in an electric circuit. If we connect two wires to a low voltage source of electric power capable of delivering a heavy current and then bring the open ends together for an instant and immediately separate them slightly, an intensely bright light is formed which is known as an arc. This arc is not only intensely bright but it is also intensely hot, so hot in fact that the wires will melt rapidly and the arc will lengthen and soon become extinguished, unless the wires are continually fed in to maintain it.

Benardos and Demetrus recognized the possibilities of utilizing the intense heat of the arc for joining metals as early as 1860. In their experiments one wire from the source of power was connected to the piece to be welded and the other to a carbon rod supported in an insulated holder. In practice the carbon is touched against the work to establish the arc and the heat of the arc so formed fuses the abutting edges of the parts to be joined. This process is known as the carbon arc process and is extensively used today. If it is necessary to add metal to the weld, it may be supplied by a filler rod or strip or from surplus metal at the joint provided for that purpose.

A few years later, Slavianoff substituted a bare metal electrode for the carbon electrode used by Benardos and Demetrus. This eliminated the necessity of adding metal through the use of filler rods as the metal electrode melted during the welding operation and furnished the additional metal required to complete the joint. This process is known as metallic arc welding and constitutes the major portion of all fusion welding in use today.

These early experiments aroused considerable interest in arc welding but little progress was made due to a lack of knowledge of the process, faulty electrodes and inadequate welding equipment. In 1900 oxyacetylene welding was successfully used in England and interest in arc welding lagged for the time. In gas welding, as in carbon arc welding, filler metal is furnished from a welding rod or surplus base metal so that the amount of metal added or heat applied can be independently controlled.

In the case of metallic arc welding, the electrode which serves as one pole of the arc also supplies the filler metal and continues to melt at a rate approximately proportional to the amount of heat dissipated in the arc. Little if anything, was then known about the effect of welding current, electrode size, welding procedure or the influence of flux coatings. Hard drawn or annealed Swedish iron and low carbon steel wire without flux coatings were used for electrodes in the early days of welding but their performance was far from satisfactory. A wide variation was experienced in the action of the electrodes in such characteristics as arc stability, penetration and deposition rate.

The fundamental value of the arc for welding is due to its tremendous dissipation of energy within a limited space, making it possible to obtain extremely high temperatures. The mere attainment of a high temperature is not the only essential requirement, for the success of the process is also dependent upon the nature of the metal transfer across the arc and the correct distribution of the available heat between the electrode and work terminals of the arc. It is through the control of the metal transfer and distribution of energy that arc stability, penetration and melting rate can be regulated to serve a wide variety of needs. However, because of the many variables which affect the electric arc, it must be closely controlled when utilized for welding. As time progressed, a knowledge of the mechanism of the arc and the effect of flux coatings was gradually acquired that permitted its successful application to welding.

A unique and important property of the metallic arc welding process is the ability to deposit metal either in a downhand, vertical or overhead position. The flow of

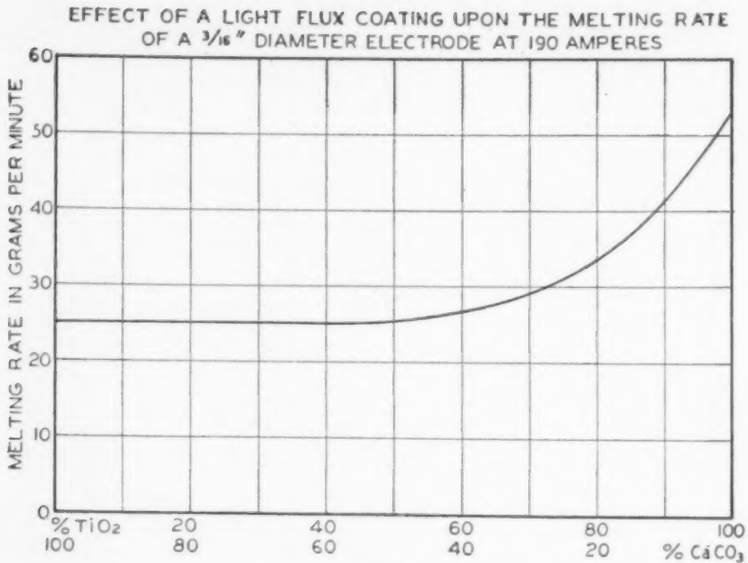


Fig. 5

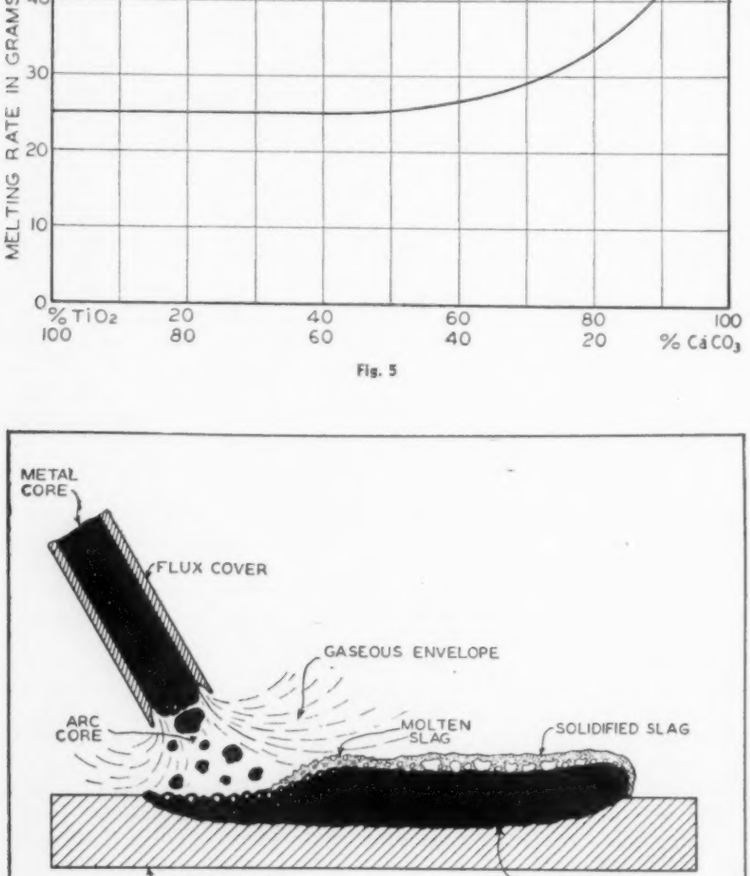


Fig. 6—Metal Transfer of Downhand Shielded-Arc Electrode

metal from an electrode across the arc to the surfaces of the parts to be joined is distinctive of the metallic arc welding process. Eschholz concluded that when welding with bare electrodes under good welding conditions, at least 85% of the deposited metal is transferred across the arc in liquid form. Briefly stated, the globular growth of liquid metal at the end of the electrode under the heat of the arc continues until the globule makes contact with the liquefied surface of the plate, whereupon the forces of adhesion and surface tension of the plate overcome the forces of cohesion and surface tension of the electrode and the molten globule is transferred.

At the moment the globule makes contact with the plate the arc is momentarily short circuited and the voltage between the electrode and plate drops from the normal arc voltage to a value of only several volts while at the same time there is an increase in the current. Thus, there is a substantial reduction in the amount of heat liberated during the period of transfer. Globular formation at the electrode terminal is characteristic of bare, processed and covered or "shielded arc" electrodes.

The size and frequency of the globular formation and duration of the individual periods of transfer vary greatly with wire analysis, diameter, flux composition and thickness, polarity, current density, arc length and circuit characteristics. The phenomena of metal transfer become of fundamental importance in the chemical and physical characteristics of the welded joint, the manipulative skill required by the operator and adaptability of the electrode.

It is essential that the arc be easily established when starting with a new electrode and that it be maintained without interruption until the electrode is consumed. However, we have just seen how the very nature of the metal transfer actually extinguishes the arc, at frequencies varying from as high as 30 times per second for bare electrodes to as low as four or five per second for covered electrodes.

The maintenance of the welding arc is dependent upon the presence of a conducting

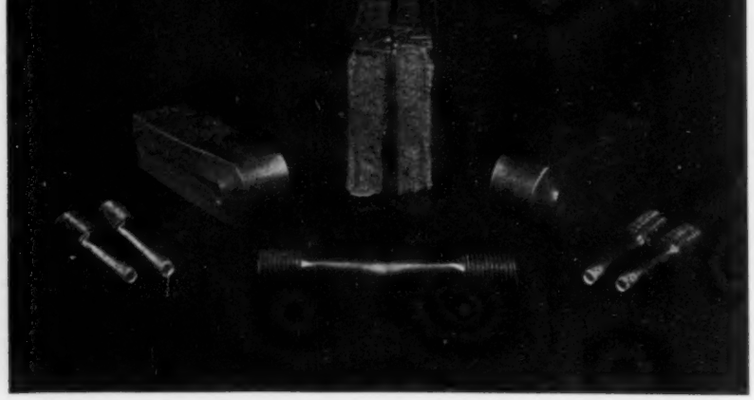


Fig. 7 (Left)—Tensile, Free-Bend and Nick-Break Specimens Machined from Weld Metal Deposited with Covered Electrodes Possess High Strength, Ductility and Soundness

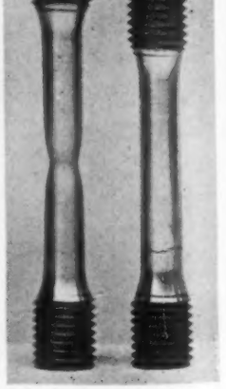


Fig. 8—Tensile Specimens Giving a Comparison of the Ductility of Weld Metal Deposited with Covered Electrodes (Left) and Bare Electrodes (Right)

gas or vapor within the arc-stream. In order to be conducting, this gas or vapor must be ionized—that is, made up of electrically charged atoms or groups of atoms that serve as carriers of the electric charges between the poles of the arc. A flux coating applied to an electrode, when heated to incandescence by the arc, will provide the necessary gas or vapor to be ionized in the arc-stream and continue to make it conductive during the period of short circuit while metal is being transferred.

It was probably a fortunate coincidence that the lime coating used to facilitate the drawing of wire possessed this property and was responsible for correcting the difficulties early workers experienced, for it, no doubt, paved the way to an investigation of the influence of fluxes. Many other materials more or less effective than calcium compounds may be used for electrode fluxes and they differ widely in their ability to emit electrons at the temperature at which emission begins, but the selection is also based upon other considerations such as melting rate of the electrode and penetration of the base metal. In general, the higher a material stands in the electrochemical series, the greater the emission; and the greater its chemical activity, the easier it is to ionize.

As an example of the influence of light flux coatings upon the melting rate of an electrode when used on straight polarity (electrode negative) with direct current, calcium carbonate and titanium oxide are selected because they exert widely different effects upon electrode characteristics. A coating of these compounds approximately 0.0001 in. thick applied separately to $^3/_{16}$ in. diameter low carbon steel electrodes will give the following melting rates at a welding current of 190 amperes:

Calcium Carbonate	25 grams per minute
Titanium Oxide	53 grams per minute

The depth to which the base metal is penetrated by the arc is inversely proportional to the melting rate of the electrode—the lower the melting rate, the greater the depth of penetration. By combining these two materials in various proportions it is possible to obtain any melting rate or depth of penetration intermediate between the extreme values obtainable with either material when used alone. This is graphically shown by the curve in Fig. 5. Other materials or combinations of materials exhibit similar characteristics.

From the above, we can say that function of a light flux coating is as follows:

(*a*) To stabilize the arc through the formation of a highly ionized vapor or gas surrounding the arc.

(*b*) To control the melting rate of the electrode and the penetration of the base metal by altering the distribution of thermal energy in the arc.

With this knowledge of the influence exerted by light flux coatings upon the melting rate, penetration and arc stability of metal electrodes, considerable advancement was made in the application of arc welding. Not only was electrode performance greatly improved but the deficiencies of the welding equipment then available became less objectionable.

Although much progress was made with the use of bare or lightly fluxed electrodes, it was soon recognized that the welds were satisfactory in strength, but low in ductility and resistance to fatigue and impact. This was found to be due to the presence of oxides and nitrides resulting from atmospheric contamination of the weld metal and vaporization of essential elements during transfer. Steel when highly heated will readily combine with the oxygen and nitrogen of the air surrounding the arc resulting in the formation of oxides and nitrides which are responsible for embrittlement of the deposit.

Kjellberg of Gottenborg, Sweden, was probably the first to recognize the possibilities of a heavy flux coating in preventing atmospheric contamination, but his discovery was only incidental to an attempt to apply a fireproof, non-conducting material to an electrode for overhead welding. In his first patent application, filed in 1907, he stated that as the electrode is consumed a crater-like cavity or crucible is formed which serves to guide the molten metal across the arc from the positive to the negative electrode or work.

Investigating the details of the process covered by his first patent, Kjellberg discovered that mechanical, chemical and physical advantages may be imparted to the weld metal by the addition of certain ingredients to the material of which the cover is made. In his second patent, issued in 1914, he specified that suitable substances may be added to the flux which in the arc develop hydrocarbons, carbon-monoxide or other reducing gases. All of the materials used or suggested by Kjellberg were essentially minerals and thus slag-forming materials, hence the name mineral or slag covered electrodes.

It was not long until the first organic-type electrode was developed. In its early form it consisted only of a metal rod with a paper winding impregnated with sodium silicate. The coating was later modified by the substitution of cellulosic flour for the paper and the addition of ferromanganese and inorganic slag-forming materials. These materials were mixed to a plastic consistency with sodium silicate and extruded upon the electrode.

Regardless of the nature of the flux used on covered electrodes—whether mineral or organic—its purpose is the same (Fig.6). When their superiority over bare and processed electrodes became generally recognized there was considerable controversy as to the relative merits of mineral and organic type fluxes. Today, however, this difference of opinion has largely disappeared and for many types of electrodes we find that the engineer has combined the outstanding advantages of both the mineral and organic fluxes to produce electrodes of highly satisfactory characteristics.

The effect of vaporization and atmospheric attack upon the composition of metal deposited with bare electrodes and the protection afforded by the flux of covered electrodes is quite clearly shown by Table 1. The composition of both the bare electrode and core wire of the covered or heavily fluxed electrode were the same.

Table 1

Element		Bare Electrode and Core of Fluxed Electrode	Bare Electrode Deposit	Covered Electrode Deposit
Carbon	%	0.14–0.16	0.02–0.04	0.08–0.12
Manganese	%	0.40–0.50	0.25 max.	0.35–0.50
Silicon	%	Trace	Trace	0.05–0.30
Oxygen	%	0.02–0.06	0.15–0.25	0.06–0.15
Nitrogen	%	0.003	0.10–0.15	0.01–0.03

Typical physical properties for welds made with bare and covered electrodes, and for the grade of base metal most generally used (0.15% carbon steel) are given in Table 2. Although the yield point and ultimate strength of metal deposited with covered electrodes are higher than for bare electrodes, the outstanding improvement is in the ductility of the deposit as expressed by elongation and reduction of area (Figs. 7 and 8). This superiority is due to the low content of oxygen and nitrogen and the absence of porosity and slag inclusions.

The high deposition rates obtainable with covered electrodes have contributed much to their popularity.

For a given diameter and current, covered electrodes will deposit from 25 to 50% more metal per unit of welding time and a still further advantage may be gained through the use of higher currents than can be satisfactorily used with bare electrodes.

Table 2

	Bare Electrode	Covered Electrode	Base Metal
Ultimate Strength, psi.	50–60,000	60–70,000	53–57,000
Yield Point, psi.	38–45,000	40–50,000	28–32,000
Elongation % in 2 In.	8.0–12.0	25.0–40.0	35.0–40.0
Elongation—Free Bend %	10.0–20.0	40.0–70.0	
Reduction of Area %	10.0–20.0	45.0–65.0	65.0–70.0
Density—Grams/cm.^{3}	7.50–7.60	7.80–7.85	7.85
Endurance Limit, psi.	16–20,000	26–30,000	26–28,000
Impact (Izod) Ft.-Lbs.	5–15	40–50	75–80

In addition to improved arc stability and control of deposition rate and penetration obtained through the use of light flux coatings, the heavy flux coating of the covered electrode serves as follows:

(*a*) To prevent atmospheric contamination of the deposited metal by the formation of a vapor or gaseous envelope or shield around the arc.

(*b*) To supply weld metal of the desired composition either by maintaining the original composition of core wire or through the introduction of additional elements.

(*c*) To retain the metal in a fluid condition, by means of a slag blanket, long enough to allow for the evolution of contained gases and the separation of non-metallic impurities.

(*d*) To utilize the heat liberated in the arc to anneal or refine the metal in the layers preceding the last deposited.

Flux compositions are usually guarded with considerable secrecy. Fundamentally, they consist of acid, basic and/or neutral slag-forming materials, arc stabilizers, deoxidizers and/or alloying materials, organic material if desired and a solution of soluble silicate for a binder. No sharp distinction can be drawn as to the function of any single ingredient of a flux for each material directly or indirectly influences one or more of the functions of the composite flux. Silica, manganese dioxide, iron oxide, amphibole, feldspar and titanium oxide or rutile may be considered as slag-forming materials while ferromanganese, ferrosilicon and silico-manganese usually function in a dual capacity as deoxidizer and for alloying additions. Sodium silicate is almost universally used as a binder.

The subject of electrode fluxes is extremely complex and involves a knowledge of metallurgy, chemistry, ceramics and circuit characteristics. In the study of these branches of science as applied to metallic arc welding, the intensity of the heat and light and the rapidity with which the cycle is completed make it difficult to take direct observations of the mechanism of the arc and metal transfer. Through the efforts of research, these handicaps have been surmounted and highly satisfactory electrodes and welding processes have been developed.

"Stove-Piping"

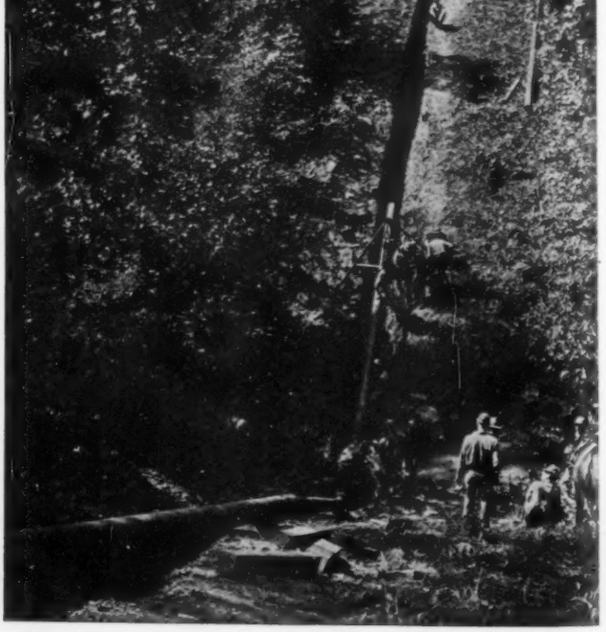
By S. C. CLARK†

Interesting Piping Procedure Used on Recently Completed Gas Line

WORK done recently on a pipe line for gas by a natural gas company in the Southeastern part of the country, is extremely interesting, because of the use made of the new "stove-pipe" method of welded pipe line construction. A total of 6 miles of 8-in. standard weight pipe was taken out of the ground, reconditioned, beveled with the use of an oxyacetylene pipe beveling machine, and relaid using gas welding.

† Technical Publicity Department, The Linde Air Products Co.

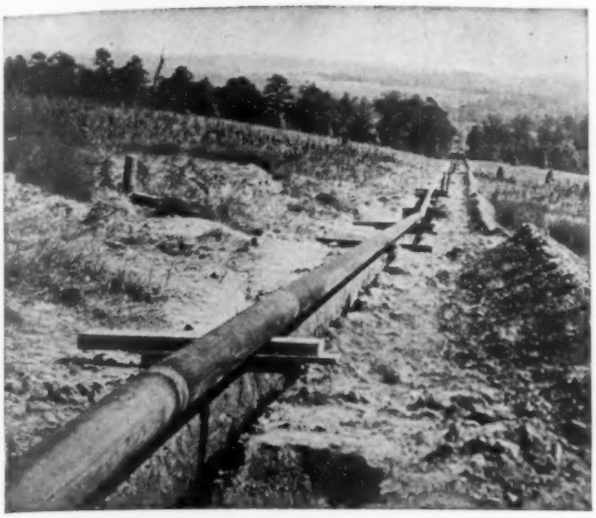
A "Grasshopper" Aligns the Pipe Section While the Operator Completes the Tack-Welds



A View of the Entire Crew Required for the "Stove-Pipe" Method of Laying Pipe

"Grasshopper" Simplifies Line-Up

One novel feature of this work was the use of a "grasshopper" which simplified the lining up and tack-welding of the pipe. As can be seen in the accompanying illustration, the "grasshopper" is simply a unit lever and fulcrum that fits on top of one length of pipe and reaches over to



A General View Along the Right-of-Way of This Southern Gas Pipe Job

pull up the next length into place. The "grasshopper" was entirely fabricated by welding from 2-in. pipe.

The illustrations show clearly how the "grasshopper" was used and how the welding operator tack-welded the pipe after alignment was made. Once the tack-weld was completed, the "grasshopper" was removed and immediately carried forward to the next joint for lining up the new section.

With this "stove-pipe" method of pipe line construction, it will be recalled that all welds are position welds. The lengths of pipe are strung out along the right-of-way, and the men begin operations all bunched together at one end. The first length is lined up on skids over the ditch. The second length is rolled up on the skids and then by means of the "grasshopper" lined up with the first length. It is then tack-welded by the tack-welding operator. He and the man who welds the "grasshopper" then move forward to the next length which is likewise lined up and tack-welded.

Two Men Work Together

Immediately behind him the welding operators make the complete bell hole or position weld. Two operators work together simultaneously on each joint. One man starts at the top of the pipe and welds down on his side completing one-quarter of the weld. At the same time, the other operator on the other side of the pipe starts at the half-way mark and welds to the bottom center-point. The first man continues to complete the welding on his side to the bottom where he meets and joins the weld of the second operator. While he is working his second quadrant the second man moves to the top and welds down on his side until all four quarters are filled in and joined completely without interference on the part of either operator. They then move on to take up the next joint the tack-welding operator has prepared for them.

A Close-Up View of a "Wrinkle" Bend Which Is Quite Satisfactory for a Gas Line

Interesting Pipe Bending Method

The method used on this line for bending the pipe for sharp bends and sags is also very interesting. The method is known as "wrinkle" bending. At the point of bend, the blowpipe flame is used to heat several narrow bands at right angles to the pipe length and extending about half way around the pipe. The pipe is then bent by means of a tractor and these heated sections wrinkle up. Of course this method is not suitable for lines carrying petroleum or oil, but it is quite satisfactory for gas lines.

It is interesting to note on this welding job that the entire welding crew consisted of so few men. There was the tack-welding operator, and the two firing line operators who followed along right behind. These, together with one helper, who also took care of the generator, and one teamster made up the entire welding crew.

Costs Are Attractive

This type of pipe laying has proved to be eminently successful under a good many circumstances. Although the immediate welding costs figured on a per-weld basis are equal to, or slightly higher than those for multi-flame gas-welding on rolling welds, the overall cost for the entire job is frequently less.

As a matter of fact, for true "stove-piping," as developed in the oil country, a pipe clamp is used instead of the "grasshopper" for lining the pipe. The "grasshopper" comes from the "stab-on" system, an even simpler organization than the one discussed here. In the "stab-on" method the pipe joints are not tack-welded but completely welded as the crew comes to the joint. Thus, the tack-welding operator is dispensed with. While the number of men is less, the mileage is also less than for "stove-piping."

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BOOK

"The Welding and Cutting Year-Book 1936–37" edited by C. Helsby, C. W. Hamann and F. J. Samuely and published by The Temsbank Publishing Co., Ltd., 12, Whitehall, London, S. W. 1. Price 5 shillings. 262 pages. Copiously illustrated. Chapters include The Progress of Welding; Recent Developments in Oxy-Acetylene Welding and Cutting Equipment and Materials. Electric Arc Welding; Atomic Hydrogen Welding; Forge Welding; Thermit Welding; Carburetted Water Gas Welding; Electric Resistance Welding; Metallurgy of Steel; Welding of Stainless Steels, Alloys and Non-Ferrous Metals; Cast-Iron Welding; Mechanics of Welds; Eye Protection for Welders; Procedure Control; Welding and Cutting Nomenclature; Testing of Welds; Training of Welders; Bibliography.

WELDING SOCIETY ACTIVITIES
AND RELATED EVENTS

A Message from Our President

To the Members of the
AMERICAN WELDING SOCIETY:

For three long, long drawn out months I have been impatiently waiting to give you this message. We are on our way! There were days and weeks which dragged interminably, days and weeks of standing by awaiting the final approval which would clear the path for what we believe will be the start of a program of advancement and progress which will be historic for the AMERICAN WELDING SOCIETY.

Many of you know something of the report of the Ways and Means Committee which was presented to, and unanimously accepted by the Board of Directors at the annual meeting in Cleveland last October. Briefly, this fine constructive report advocated the following:

THE AMERICAN WELDING SOCIETY should adhere aggressively to its basic policy in order that the science and art of welding may be advanced with the most rapid strides. To accomplish this, it was recommended that in the interest of efficiency the Headquarters Staff be materially increased; that the personnel of this management consist of a Managing Director, a Technical Secretary, a General Secretary and Office Manager, and Editor of the Journal and an adequate clerical staff. It was suggested that the Managing Director have general charge of the above staff, that he be a person who can successfully "sell" the Society to industry; that he shall cooperate with other technical societies, educational institutions, and with legislative bodies giving consideration to laws affecting welding; that he shall work with the Membership Committee to increase the sustaining and other grades of memberships. It was recommended that the Society proceed immediately to edit and publish a Welding Handbook which shall cover the entire field of welding both in its technical and practical aspects. (This work is now well in hand.)

There were other definite suggestions covering the method of Society Management under a new scheme of Vice-Presidents. The report of the Ways and Means Committee is presented in its entirety in this issue of the Journal.

Naturally, all of this could not be undertaken or successfully pursued within the present budget of the Society. This was realized by the Ways and Means Committee and suggestions for its underwriting were presented. The working out of this underwriting was the reason for the delay which has been encountered. Your Committee has not been idle. We have received definite assurance of an underwriting of twenty thousand dollars a year for a three year period. This is two-thirds of the goal set and is sufficient to allow us to proceed without further delay. It is the definite decision of your President, the Board and the Committee on Management that no expense beyond our underwriting be incurred. The funds available may not allow us to put our full program in force at once but we can make a definite beginning with the most essential item, namely, the employment of a Managing Director. We are confident that the balance of our underwriting will be accomplished.

Because the effective period of our fiscal year has but four months left before summer, the first objective of the new Manager will be the endeavor to establish some six or more new chapters. The ground work has been well laid and we believe there will be no great difficulty in accomplishing this objective. Since Mr. Davis, our Membership Committee Chairman, took office last summer we have obtained 33 new sustaining members. New members of all grades received in the last three months are as follows: October—64, November—92, December—111; a total of 267 in three months. The Society is grateful to Mr. Davis and his Committee for this splendid showing. This justifies the faith of many of us that there is a wide field of action for the Society and all that is needed is interest on the part of the rank and file and a belief in the Society and what it has to offer to those associated with the development and use of welding in all its manifold phases.

The progress which the AMERICAN WELDING SOCIETY will make in this next three year period will give to the science and art of welding as great as impetus as it has yet known. Our new plan of action is but one phase. Our fundamental research sponsored jointly by the AMERICAN WELDING SOCIETY and the American Society of Electrical Engineers with the Engineering Foundation is bound to increase greatly our knowledge of the basic fundamentals. This knowledge is very important to progress. Our work on codes and nomenclature and symbols, our qualifications of materials and practices, our striving for order and procedure, and definite clear cut widely accepted manner of doing things is not only technically important as a contribution to science but will be a great imaginable boon to welding.

The AMERICAN WELDING SOCIETY acknowledges with gratitude and pride the twenty thousand dollars underwriting by the Electrical industry (Welding Section of NEMA) and the Gas industry (manufacturers of welding and cutting gases.) I acknowledge these splendid contributions with gratitude because it makes our program possible, I acknowledge it with pride because I realize that industry feels that the work we are doing is of great importance to the swift, orderly and constructive industrial growth of welding.

Now, just a note about myself; this is being written at the beginning of my eighth day of lying on my back in Grace Hospital, Cleveland. There was quite a bit of heat in the conversation between my surgeon and myself about my going to Pittsburgh last Wednesday to speak before the joint meeting of the AMERICAN WELDING SOCIETY and the Western Pennsylvania Engineers Society. It ended as those arguments always end; I went to the hospital.

They won't tell me when I can leave here, they won't allow any visitors except my wife and children, they won't allow me to go back to work for more than a month, and so, whether I like it or not, the boss, the doctor and the wife have gotten their heads together and I hear, "Port of Spain," and "Haiti," and "Canal Zone." Well, I won't take any responsibility. I'll probably go because there isn't anything else I can do about it, but they certainly aren't going to get me in the position where I can't come back and say, "Who the Hell picked out that kind of a vacation for a welder?" Funny what a little thing like an appendix can do to a big, healthy, shop hand; isn't it?

Now you know the story of what we have done so far and you know what we are proposing to do. I am confident of your united support and I promise you that we on the Management Committee are going to give this problem all we possibly can so that out of it may grow a larger more effective society through which the science and art of welding will put on seven league boots.

Sincerely yours,
A. E. Gibson, *President*
AMERICAN WELDING SOCIETY

P. S. The die has been cast for Florida instead of the West Indies. The one hard part is that they are locking up my golf clubs. Maybe they'll let me caddie and I can earn Mrs. Gibson's and my expenses while away.

And lest I forget—did you get your MAN, your new member?

Report of Ways and Means Committee, American Welding Society

Committee Assignment

This Committee was appointed by authorization of the Board of Directors at the meeting of February 4, 1936, with instructions to recommend ways and means of carrying out a program which had been proposed to the Board at that meeting and which involved greatly expanded activities of the Society.

The Committee has interpreted these instructions to include the reformulation of a statement of policy with respect to activities in which the Society may properly engage and a list of the more important of such activities, in addition to proposing the "ways and means" for carrying out such an expanded program.

To assist the Committee in its consideration of this assignment, the Chairman had solicited the comments and suggestions of 36 prominent and representative members of the Society in a letter dated April 3, 1936, While a total of only 19 of these members responded to this communication despite follow-up requests, these responses contained a great many constructive comments and suggestions which in the majority of cases showed thoughtful study of the Society's problems. All of these suggestions had been collated and classified by the Chairman in a document of something over 20 closely spaced typewritten pages, and circulated to the members of the Committee well in advance of this meeting. As stated above, all of this material was carefully considered in arriving at the conclusions and recommendations contained herein.

Objects of the Society

(*A*) It is the opinion of the Committee that the statement of objects of the Society as given in Article II of the Constitution are adequate to cover any activities which may properly be undertaken and sponsored by the Society as a technical organization.

(*B*) The first of the objects listed in Article II, namely, "To advance the science and art of welding," is interpreted and amplified by this Committee as follows:

Advancement of the art and science of welding means the extension of the use of welding and flame cutting as applied arts by spreading the knowledge of these processes, by aiding and improving, both technically and economically, present applications and by aiding in the extension of these applications in new fields.

Type of Organization

The universal opinion expressed in the comments of members reviewed by the Committee, confirm the unanimous opinion of the Committee that the Society should continue to function as a solely technical organization as distinguished from a trade organization. It is recognized that "advancement of the art of welding" really means in the end, expansion of the application of welding so that it becomes of greater and greater commercial importance. While, therefore, the "dollars and cents" phase of the welding industry is the motivating element, it is the opinion of the Committee that the Society can be most useful even for this purpose, by restricting its activities to those of a strictly technical character. Welding is a tool for the manufacturing and metal fabricating industries in competition with other methods of joining metals. These are all technical industries; consequently it is necessary that much of the "propaganda" be technical and further, that such activities be sponsored by an organization which is recognized as being independent of any particular commercial interest. The American Welding Society has functioned as just such a body, has already attained considerable prestige and, therefore, for the most satisfactory advancement of the commercial interests concerned with welding, the Society should remain as a strictly technical organization.

Organization

It is recognized that the staff of the Society as at present constituted, is not in position to effectively carry out the program proposed above. It is, therefore, recommended that the salaried staff *be reorganized* with the following personnel:

(1) A Managing Director who shall be in general charge of the activities of the Society under the supervision of the President and Board of Directors.

The duties of the Managing Director are to include in addition to the general supervision of the staff activities, the acquainting of industry with the work of the Society and the obtaining of the financial support of the industry of the Society's activities, the building up of the membership, particularly the sustaining member and associate member grades, and contacting with and aiding the local sections in their activities in carrying out the objectives of the Society.

The Managing Director should be a technical man well-known to the industry, and have the personality and presence of a successful contact man in order to effectively "sell" the American Welding Society to industry.

(2) An Engineering Secretary who shall serve as an assistant to the Managing Director with respect to technical matters, particularly in the assistance of the technical committees, and in the coordination and speeding up of their work, thus reducing an objection inherent in an activity carried out by a voluntary committee, the members of which cannot be expected to devote unlimited time to the work.

(3) An Editor who will edit the Journal and carry on such other editorial work as may be assigned by the Managing Director.

Elected Officers

It is suggested that the elected administrative officers of the Society be assigned to functional responsibilities rather than to general supervision of the Society's activities in a broad territory, as is now the case. In doing this, the necessity should be borne in mind of selecting men representing all of the various industrial sections of the country. A suggested arrangement of this order would involve the election of a President, as the major executive, possibly a first Vice-President, and possibly three Vice-Presidents whose responsibilities might be as follows:

Vice-President in charge of engineering and technical activities

Vice-President in charge of membership and finance

Vice-President in charge of meetings, publications and section activities.

In this type of organization, the chairmen of the various committees could report through the Vice-President specifically responsible for particular activities. Questions for discussion before the Board of Directors or the Executive Committee should be submitted to these Vice-Presidents for study and recommendation. This should simplify the work of the Executive Committee and the Board of Directors. It should decrease the necessary amount of detail work of the President and, in this regard, justify an invitation, even to very busy men, to accept major administrative offices in the Society. The necessity of this type of organization should be considered in connection with the assumption that a general reorganization of the Society's functions will greatly increase the work of the Society and would, therefore, increase the burden which now falls heavily on the President and the hired staff.

At the present time, the regional Vice-Presidents take very little active part in the affairs of the Society. This proposal would bring such men into active Society work and would bring about the selection of men properly qualified by training and experience to handle the details of specific types of Society activity.

Finances

It is estimated that to carry out the above program, $30,000 additional revenue would be required the first year. This estimate is based on the following budget of expenditures:

Salaries of Managing Director and Engineering Secretary	$15,000
Traveling Expenses	4,000
Additional clerical assistants	3,000
Miscellaneous (additional rent, printing, etc.)	4,000
Contingencies	4,000
	$30,000

It is the opinion of the Committee that this sum should be underwritten by industry and it is believed that it could be obtained in accordance with the following approximate allocation:

From the supplies industries	$20,000
From other industries (users of the welding processes)	10,000

The Committee is of the opinion that during this first year the income from increased membership and advertising could be made not less than the following:

100 sustaining members	$10,000
500 regular members	5,000
Increased advertising	3,000
	$18,000

This would reduce the underwriting for the second year by more than fifty per cent. With continued energetic efforts the

growth of the Society should increase to an extent where special underwriting should not be required longer than the third year at the most.

Welding Handbook

The Board of Directors' action establishing this Committee included in the assignment the recommending of action to be taken with respect to the proposed Welding Handbook.

The majority of the Committee approves the proposal that a handbook on welding be prepared and published by the Society. It is believed that it would be a very worthy activity of the Society, if a practicable means of producing such a book can be developed, and if and when the Society's structure is reorganized in line with the recommendations made in this report. However, the Committee recommends that the plan that has been proposed for the preparation of this handbook be carefully reviewed and that consideration be given to the revision of the proposed outline.

In making the estimates listed on page 28 no account has been taken of the financing of the handbook because it is understood by this Committee that arrangements would be made to finance that publication quite independent of Society funds.

Respectfully submitted,
C. A. Adams
A. F. Davis
F. M. Farmer
C. D'W. Gibson
L. D. Meeker
J. B. Tinnon
T. C. Fetherston, *Chairman*

Actions Taken by the Board of Directors at Its Oct. 19th Meeting in Regard to the Appointment of the Ways and Means Committee

"Research"—It was pointed out by a member of the Committee that no mention is made in the report of this vital activity of the Society because of the fact that the Engineering Foundation Welding Research Committee (jointly sponsored by the A. I. E. E. and AMERICAN WELDING SOCIETY) is now organized to take care of this part of the Society's work. The work of the Welding Research Committee and the financing thereof is being pushed vigorously. Thus far most of the financial support has come from the users of the welding processes, and the desirability of again approaching this group in support of the proposed re-organization program was questioned.

"Committee Assignment," "Objects of the Society" and "Type of Organization." These items were approved as set forth in the report, although it was felt that the Society should go no faster in the expansion of welding applications than the fundamental knowledge of the subject warranted.

"Organization"—Questions arose as to the feasibility of embarking on too large a program at the beginning. It was felt that it might be best at first to engage only a Managing Director and enlarge the organization as finances permit. In answer it was stated that the Committee to be appointed to consider details would be instructed that the Society cannot obligate itself any further than its finances for this work permit. Attention was called to the fact that no provision had been made for a Secretary other than an Engineering Secretary. It was definitely stated that the personnel proposed under this heading is to be in addition to the present staff. With this understanding the recommendations of the Committee were approved.

"Elected Officers"—Proposal for Functional Vice-Presidents was given serious consideration. It was felt that while such arrangement is satisfactory in an industrial organization, it might not be successful in a technical society as much would depend upon the type of men elected, their familiarity with the respective fields and their willingness and ability to devote the required time to the job. It would be difficult to get the right type of men since they are to be elected rather than appointed, and since consideration has to be given to geographical distribution. Possible confliction of duties of functional Vice-Presidents with the duties of certain committees and the paid staff, was pointed out. After deliberation it was deemed best to refer this item for further study to the Committee to be appointed to consider details.

"Welding Handbook"—It was the concensus of opinion that since the financing of the Handbook is to be independent of the Society's funds, there is no reason for further delaying the publication awaiting the accomplishment of the re-organization of the Society. (Plans for the publication of the Handbook were then reviewed.) After deliberation, it was

Voted: That the report of the Ways and Means Committee be accepted with sincere thanks to the Committee, and a deep appreciation of the vast amount of time and effort spent by all members of the Committee in the study of this problem and in the preparation of this constructive eport.

The President requested authority to appoint a Committee consisting of two users of the welding processes, two representatives of the electric, and two representatives of the gas welding industries to secure the needed funds and settle the necessary details to carry out the essence of the report. He had in mind the ap pointment of such men as Mr. A. F. Davis. He hoped the Board would have sufficient confidence in him to grant his request.

It was further

Voted: That the President be empowered to take such steps as he deems necessary to carry out the essence of the report of the Committee on Ways and Means with regard to all matters covered therein, with the exception of that dealing with the Welding Handbook.

It was further

Voted: That the Welding Handbook Editorial Committee be instructed to proceed with the publication and issuance of the Welding Handbook at the earliest possible moment.

Welded Ship

The new tanker to be built for the Atlantic Refining Company in the Chester, Pa. shipyard of the Sun Shipbuilding Company, will be the world's largest welded ship, The Atlantic Refining Company announced. With a dead weight tonnage of 18,500 tons, the new oil carrier will also be the largest commercial vessel under construction in American shipyards.

The new Atlantic tanker will have a length of 521 feet between perpendiculars, a beam of 70 feet and a cargo capacity of 156,000 bulk barrels of gasoline. Turbo-electric engines developing 5000 horsepower will give the vessel a speed of over 13 knots, enabling it to make the trip between Philadelphia and Texas gulf ports in the unusually fast time of six days. It will carry a crew of 8 officers and 26 men.

Preliminary construction work has already been started and the vessel is scheduled for delivery to The Atlantic Refining Company by the end of the year.

Obituary

WILLIAM P. BOWMAN

William Pitcher Bowman, vice-president and treasurer of John A. Roebling's Sons Company of New York and former Republican New Jersey State Committeeman, died Jan. 22nd in the Post-Graduate Hospital, New York City, after a short illness. He was 68 years of age. His home was at South Branch N. J.

Mr. Bowman also was president of the Durable Wire Rope Company of Boston and a director of the Raritan, State Bank of Raritan, N. J.

Mr. Bowman was active in the affairs of the AMERICAN WELDING SOCIETY and took a keen interest in the Filler Metal Specifications.

Mr. Bowman also was a member of the Lotos Club, The Engineers' Club, the Bankers' Club, the Railroad Machinery Club of New York and the Raritan Valley Country Club of Summerville, N. J.

EDWARD M. SEXTON

Edward M. Sexton, Railroad Sales Manager of Air Reduction Sales Company, died February 15, 1937 in New York after an illness of several weeks. He was fifty-six years old.

Mr. Sexton was born on Staten Island and was educated in the public schools there. Previous to his connection with Air Reduction, he was in the Sales Department of Holt & Co., flour merchants, and the Western Electric Company, which he represented in Chicago and Denver.

"Ted" Sexton, as he was known to a host of friends in railroad circles and to practically everybody in his company, began his career with Air Reduction as a salesman in the Metropolitan district in 1916. Later he was appointed Manager of the Chicago district and from this position he was transferred back to New York as Manager of the Metropolitan district. When in 1922 the Davis-Bournonville Company's personnel was merged with Air Reduction, he was selected to manage the Railroad Sales Department, with headquarters in New York.

Research and Specifications

The American Railway Engineering Association Bulletin No. 38, Volume 391, dated November 1936, contains the report of the Committee on Iron and Steel Structures. The Conclusions of this report, which appear on page 307 of the Bulletin, are as follows:

"It is apparent that the practice of welding is in advance of theory and somewhat ahead of exact knowledge. There is a large field for research and experimental work, and a great deal is being done in all parts of the World. So much knowledge is now available that there need be no hesitation in applying welding to repairs and reinforcement. All-welded work should be adopted only after a thorough study, both technical and economic.

"Consistent specifications should be adopted and rigidly enforced. Qualified operators and experienced inspectors should be employed. It is particularly necessary that the work be designed and the sequence of welding operations be outlined by a competent engineer experienced in fabricating welded steel structures.

"The 'Specifications for Design, Construction and Repair of Highway and Railway Bridges by Fusion Welding' of the AMERICAN WELDING SOCIETY for 1936 cover in detail the materials, equipment processes, workmanship and inspection of gas and arc welding as applied to bridgework, new or old. These specifications may be obtained from the AMERICAN WELDING SOCIETY, 33 West 39th Street, New York City."

Ohio State University Welding Conference to Be Held March 3, 4 and 5, 1937.

The Department of Industrial Engineering, Ohio State University, Columbus, Ohio, announces March 3rd, 4th and 5th as the dates for the Sixth Annual Welding Conference and Exposition at Columbus. This conference annually attracts many men interested in manufacture and use of welding equipment.

This year's conference will include a special three day course in arc welding design and practice presenting material of interest to all men who are interested in welding—Architects, Engineers, Designers, Production Managers, Welding Supervisors, Foreman and Operators. The Course will be under the direction of E. W. P. Smith, nationally known welding authority of Cleveland, Ohio.

The purpose of the Course is to study the arc welding process and its application to design and fabricating problems. The process will be considered from the arc to the finished product. Following subjects will be covered:

The Shielded Arc, Its Value and Use in Design: Welding Ferrous and Non-Ferrous Metals; Use of Special Electrodes; Weld Inspection, Checking Fusion and Penetration; Calculating Stress Distribution in Welded Joints; Use of Polarized Light and Weld Models of Rubber and Celluloid; Arc-Welded Design as Applied to Structures and Dwellings; Redesign of Cast and Riveted Machine Structures for Arc Welding; Organizing the Welding Department; Estimating Welding Costs.

The Course will consist of morning and evening sessions devoted to lectures and practical welding demonstrations.

Complete information regarding the Welding Conference and the special course in arc welding design and practice can be obtained by writing to O. D. Rickly, General Chairman, Sixth Annual Welding Conference and Exposition, Department of Industrial Engineering, Ohio State University, Columbus, Ohio.

Welding Prizes

By A. F. DAVIS†

One of the richest awards ever established for competition in the field of mechanical science has just been announced by the James F. Lincoln Arc Welding Foundation.

To stimulate intensive study of arc welding, $200,000 will be distributed by the Foundation among winners of 446 separate prizes for papers dealing with this subject as a primary process of manufacture, fabrication or construction in eleven major divisions of industry.

The principal prize winner will receive not less than $13,700. Other prizes range from $7500 to $100—the latter sum to be awarded each of 178 contestants who receive no other prize, but whose papers are adjudged worthy of honorable mention.

In order to assure equal competitive opportunity, similar prizes are offered in the eleven major divisions of industry covered by the contest. These divisions are: Automotive, Aircraft, Railroad, Watercraft, Structural, Furniture and Fixtures, Commercial Welding, Containers, Welderies, Functional Machinery and Industrial Machinery.

Wide diversification of awards is effected by further dividing each major industry into various sub-classifications; with entrants required to select in advance the particular sub-classification to which their papers will relate.

When accepted by the Jury of Awards as properly classified, each paper will be in competition, in its particular sub-classification, for five initial prizes established for that group. These are worth, respectively, $700, $500, $300, $200 and $150.

From among these sub-classification winners, four papers will be selected in each major industry to receive additional prizes of $3000, $2000, $1000 and $800. Thus, these 44 semi-finalists will be awarded a total of $74,800.

In addition, the semi-final winners in the various divisions will be considered as possible recipients of the four Main Prizes. These range from $10,000 to $3500, with the winner of the Grand Prize receiving not less then $13,700 for his paper.

† Secretary, the James F. Lincoln Arc Welding Foundation P. O. Box 5728, Cleveland, Ohio.

Analysis of the complete prize offering shows the following:

1. In the Automotive field, twenty-four prizes with a total value of $14,200. These to be awarded papers submitted under four sub-classifications; namely, Engines, Bodies, Frames and Trailers.

2. In the Aircraft field, fourteen prizes with a total value of $10,500. Sub-classifications for the Aircraft industry are two; namely, Engines and Fusilage.

3. In the Railroad field, twenty-four prizes with a total value of $14,200. Four sub-classifications are made of the Railroad industry; namely, Locomotives, Freight Cars, Passenger Cars and Locomotive and Car Parts.

4. In the field of Watercraft, fourteen prizes with a total value of $10,500 are established. Sub-classifications in this division of industry are two; namely, Commercial and Pleasure.

5. In the Structural field, twenty-four prizes are offered; with a total value of $14,200. Four sub-classifications are established in this division; namely, Buildings, Bridges, Houses and Miscellaneous.

6. In the Furniture and Fixtures division, the prizes number fourteen; with a total value of $10,500. Two sub-classifications are set-up; namely, House and Office.

7. For the Commercial Welding division, fourteen prizes worth a total of $10,500 are set-up. The two sub-classifications established are: Job Shops and Garages.

8. In the Containers division, fourteen prizes with a total value of $10,500 are established. This division is split into two sub-classifications; namely, Contents Stationary and Contents Moving.

9. In the division of Welderies, $10,500 will be distributed in fourteen prizes. This division has two sub-classifications; namely, Commercial and Departments of Plants.

10. In the Functional Machinery division, fifty-four prizes with a total value of $25,300 are set-up. This division is partitioned into ten sub-classifications; namely, Metal Cutting, Metal Forming, Electrical, Prime Movers, Conveying, Pumps and Compressors, Business, Jigs and Fixtures, Parts, and not otherwise classified.

11. In the division of Industry Machinery, prizes number fifty-four, with a total of $25,300. This division also has ten sub-classifications; namely, Process, Construction, Petroleum, Steel Making, Farming, Household, Food-Making, Textile and Clothing, Printing, and not otherwise classified.

To participate in this contest, it is necessary that submitted papers describe either the redesign of an existing machine, structure, building, etc., so that arc welding may be applied to its manufacture; or that they present a design (either in whole or in part) of a machine, structure, building, etc., not previously made—the description to show how a useful result, which was impractical with other methods of construction or could better be done by arc welding, is obtained.

In certain classifications, however, slightly different eligibility requirements obtain. In the divisions of Commercial Welding and Welderies, for example, owners and operators of functioning establishments may enter the competition with papers which describe details for successfully conducting such a business.

Contestants, it was announced, must have papers in duplicate on file with the Secretary of the Foundation, at Cleveland, Ohio, not later than June 1, 1938. Prospective entrants should communicate promptly with Foundation Secretary A. F. Davis, P. O. Box 5728, Cleveland, for complete details of the rules and conditions covering awards.

This competition, with its long list of valuable prizes, marks the first announced activity of the Foundation since its establishment, at the close of 1936. Already, however, the Foundation has received wide acclaim among educators and publishers in the engineering world.

While many industrial methods and new processes of great benefit have been made available in recent years with the aid of the electric arc, Dr. E. E. Dreese, Head, Department of Electrical Engineering, Ohio State University, Columbus, and who is Chairman of the Jury of Awards of the competition, has pointed out that the full measure of arc welding's value in industrial production has hardly been tapped.

Dr. Dreese emphasized the fact that the competition may be entered by any person, or group of two or more persons; the sole limitation being that any contestant may enter only one paper, on only one subject, in only one of the subclassifications listed.

Further, each contestant must actually have participated in work upon which the subject matter of his paper is based; and the contestant's exact relation to that work, and to the producing or developing organization, must be clearly stated.

Employers are particularly invited to urge their qualified workers or associates to communicate with the Foundation, promptly, and prepare to submit papers for some of the substantial awards offered

SECTION ACTIVITIES

CHICAGO

An Open Forum on "Welding Non-Ferrous Metals" was held by the Chicago Section on January 15th at the Armour Institute of Technology. Mr. W. C. Swift, of the American Brass Co., spoke on "Copper and Its Alloys;" Mr. F. G. Flocke, of the International Nickel Company, spoke on "Nickel and Its Alloys;" and Messrs. G. O. Hoglund and W. M. Rodgerson of the Aluminum Company of America, covered the subject "Aluminum and Its Alloys." Dinner at 6:15 preceded the meeting. At 7:15 sound movies on several sporting subjects ("Thrills and Spills, Etc.") was shown as an added feature.

The February 19th meeting will be devoted to the "Relations of weld metal to base metal," with Mr. L. C. Bibber of the Carnegie-Illinois Steel Corp. as speaker. Mr. Bibber will also discuss welding symbols.

CLEVELAND

On Wednesday evening, January 13th, the Cleveland Section had the pleasure of having Mr. Jack Gordon of the Taylor Winfield Corp. of Detroit as its speaker and the meeting was one of the best held in several years, having an attendance of over two hundred and fifty. This meeting was arranged through the cooperation of the NEMA Welding Section. Mr. Gordon spoke on "Why Use Fabricated Steel?".

DETROIT

A joint meeting of the Detroit Sections of the AMERICAN WELDING SOCIETY and the American Society for Metals was held on February 12th at the Hotel Stattler. Dr. Armand DiGiulio, Metallurgist, of the Ford Motor Company spoke on the subject "Metallurgical Factors of Welding."

A paper on "Applications of Fusion Welding in the Tool and Die Industry" is planned for the March meeting.

MARYLAND

An industrial sound equipped motion picture of the manufacture, uses and applications of Enduro Stainless Steel as prepared by the Republic Steel Corporation was the feature of the meeting on January 15th. After the showing, the meeting was thrown open for general discussion and Mr. T. R. Lichtenwalter of the Metallurgical Department of the Republic Steel answered many questions and gave a short talk.

MILWAUKEE

The regular monthly meeting of the Milwaukee Section was held on January 21st at the Milwaukee School of Engineering. Mr. Harold Verson, Chief Engineer of the Allsteel Press Company, spoke on "Problems of Welding in Machine Tools."

NORTHERN NEW YORK

A very successful meeting sponsored by the Northern New York Section for the Schenectady Engineering Societies was held on January 21st with a total attendance of approximately 400. Sound motion pictures of the San Francisco-Oakland Bay Bridge were shown as were, also, motion pictures of the Golden Gate Bridge.

PHILADELPHIA

A joint meeting of the Philadelphia Section of the A.W.S. and Philadelphia Chapter of the American Society for Metals was held on January 29th at the Engineers' Club. "The Metallurgy of Welding" was presented by Mr. Everett Chapman, President, of Lukenweld, Inc., and "Facts and Figures" was presented by Mr. W. Eisenman, National Secretary of the A.S.M.

The following are the speakers and subjects for the February, March and April meetings of the Philadelphia Section.

February 15th—"The Electric Welding of Monel, Nickel and Nickel-Clad Steel," by F. G. Flocke, Technical Service Department of the Development and Research Division of the International Nickel Co.

March 15th—"Solving Manufacturing Problems by Welding," by C. H. Jennings, Engineer in Charge of Welding Research, Westinghouse Elec. & Mfg. Co.

April 19th—Sound equipped moving pictures of "Manufacture, Uses and Applications of Enduro Stainless Steel," to be presented by T. R. Lichtenwalter, Welding Expert, Metallurgical Dept., Republic Steel Corp.

PITTSBURGH

A joint meeting of the Pittsburgh Section of the A.W.S. with the Engineers Society of Western Pennsylvania was held on January 27th at the William Penn Hotel. Mr. A. E. Gibson, President of the A.W.S. and Vice-Pres. of the Wellman Engineering Company, spoke on "Why We Weld;" and Mr. A. B. Einig, General Manager of Motch & Merryweather Machinery Co., presented a lecture on "Industrial Conditions in Russia."

SAN FRANCISCO

The regular monthly meeting of the San Francisco Section was held on January 22nd at the Athens Athletic Club, Oakland. Mr. K. V. King continued his interesting survey of important current welding literature with emphasis on the splendid articles appearing in the Journal. The principal speaker was Mr. C. S. Fuller, in charge of Gas Construction and Operation, Pacific Gas & Electric Co., who addressed the meeting on the subject "Welding on High Pressure Gas Lines."

EMPLOYMENT SERVICE BULLETIN

SERVICES AVAILABLE

A-235. Electric Welder with twenty years' experience desires position.

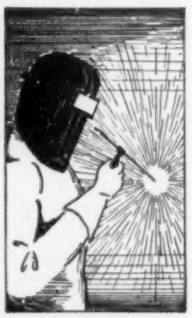
A-236. Metallurgical Engineer immediately available. Lehigh University graduate. Age 27. Four years of practical experience. Can initiate and direct research. Worked 1½ years with electrode manufacturer in charge of laboratory. Experienced in heat treating, testing, metallography, as well as, all types of Welding. A1 references.

POSITIONS VACANT

V-74. Salesman for procurement of welding orders for an organization engaged in salvaging gas and Diesel engine parts capable of contacting with engineers and executives in railroad and steamship shops and offices.

V-75. Welding shop fabricating A. P. I.-A. S. M. E. Code Vessels desires an inspector familiar with the various codes and Class I welding procedures.

WELDING ROD COATING MATERIALS AND FLUXES



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